LBL Research Progress Meeting

Electromagnetic Signatures in ATLAS in the 7 TeV Data

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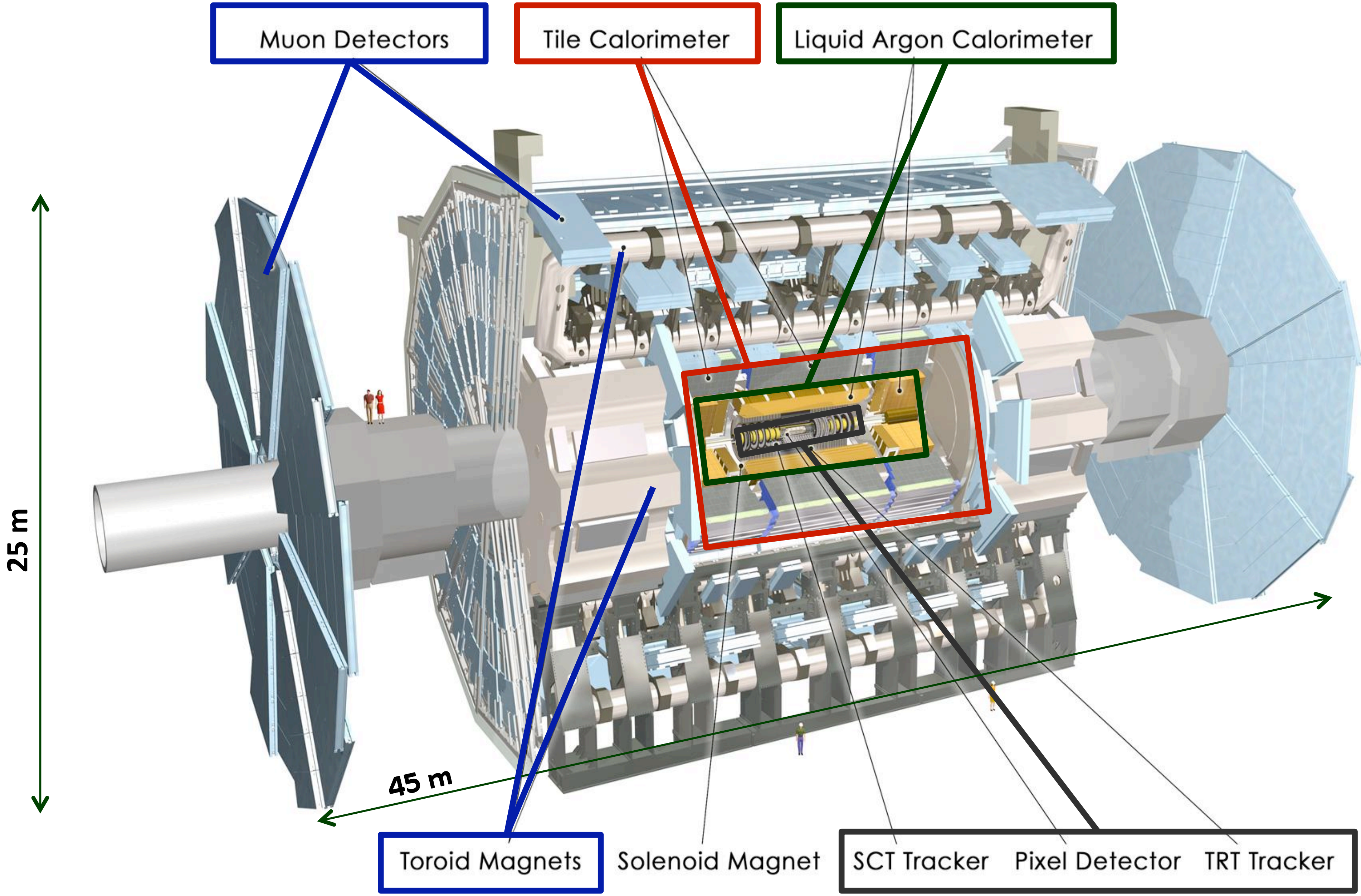
Overview

- LHC and ATLAS detector operation and status
- Reconstruction of electrons/photons
    - ATLAS sub-systems
    - Electron/photon identification
- Observation of prompt electrons
    - Signal identification
    - Extraction of components and systematic uncertainties
- Electrons from J/ψ decays
    - Reconstruction of J/ψ invariant mass
- Electrons from W/Z decays
    - Signal identification
    - Cross-section measurement
    - Charge asymmetry in W decays
    - Electromagnetic energy scale
- Observation of prompt photons
    - Signal identification and efficiency
    - Measured photon purity
- Material mapping of the ATLAS tracker with converted photons
    - Towards a realistic description of the ATLAS detector

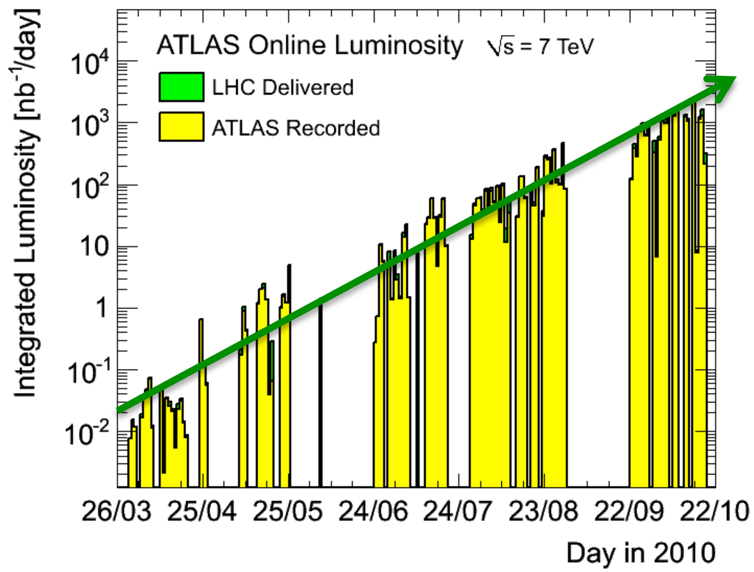
A Toroidal LHC ApparatuS



LHC and ATLAS Performance

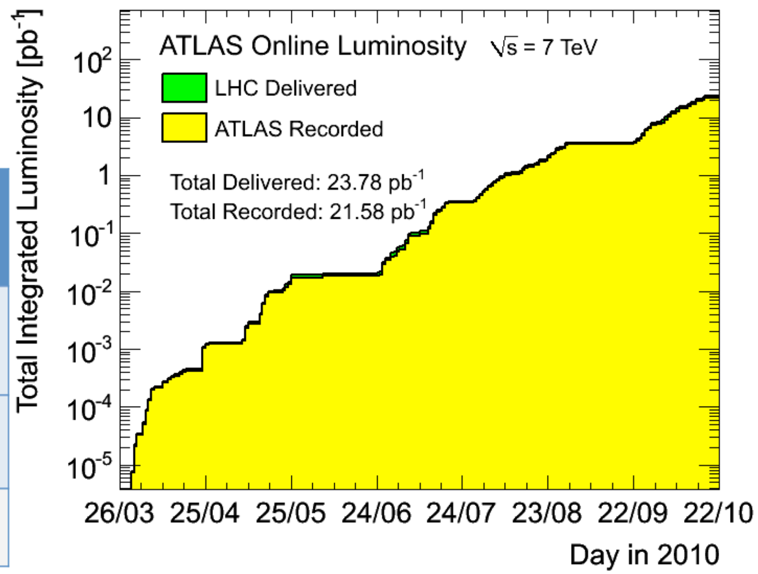
Life in a new accelerator is very exciting:

- Integrated luminosity increasing almost exponentially!



ATLAS is operating well:

- Recorded almost all delivered luminosity
- Sub-systems operational ~100% of time



Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	TGC	CSC
96.7	97.5	100	93.8	98.8	99.0	99.7	98.6	98.5	98.6	98.5

Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams at √s=7 TeV between March 30th and August 30th (in %)

The ATLAS Tracker

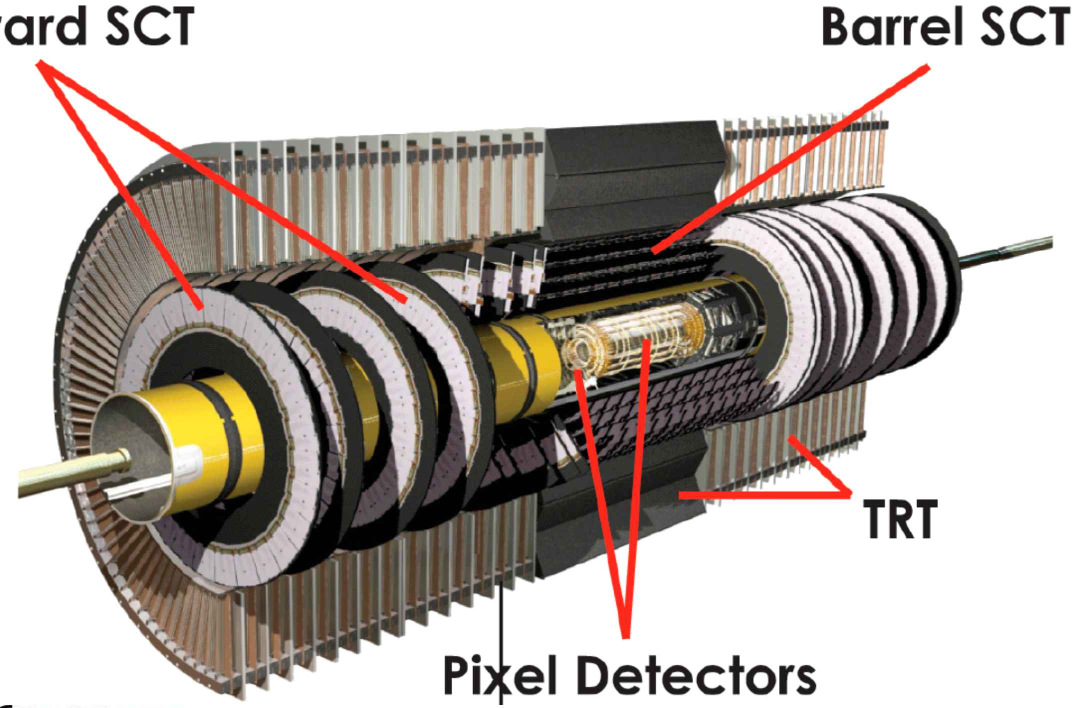
The Inner Detector (ID) is organized
Into three sub-systems:

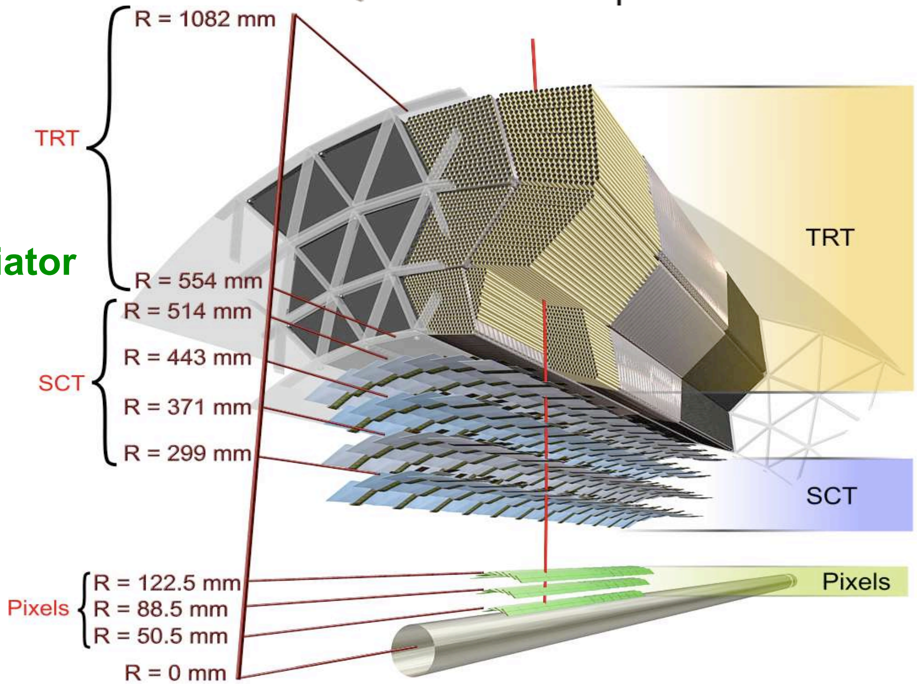
Pixels
- high resolution space points
- 1 removable barrel layer
- 2 barrel layers
- 4 end-cap disks on each side
- (0.8 10^8 channels)

Silicon Tracker (SCT)
- silicon microstrips
- 4 barrel layers
- 9 end-cap wheels on each side
- (6 10^6 channels)

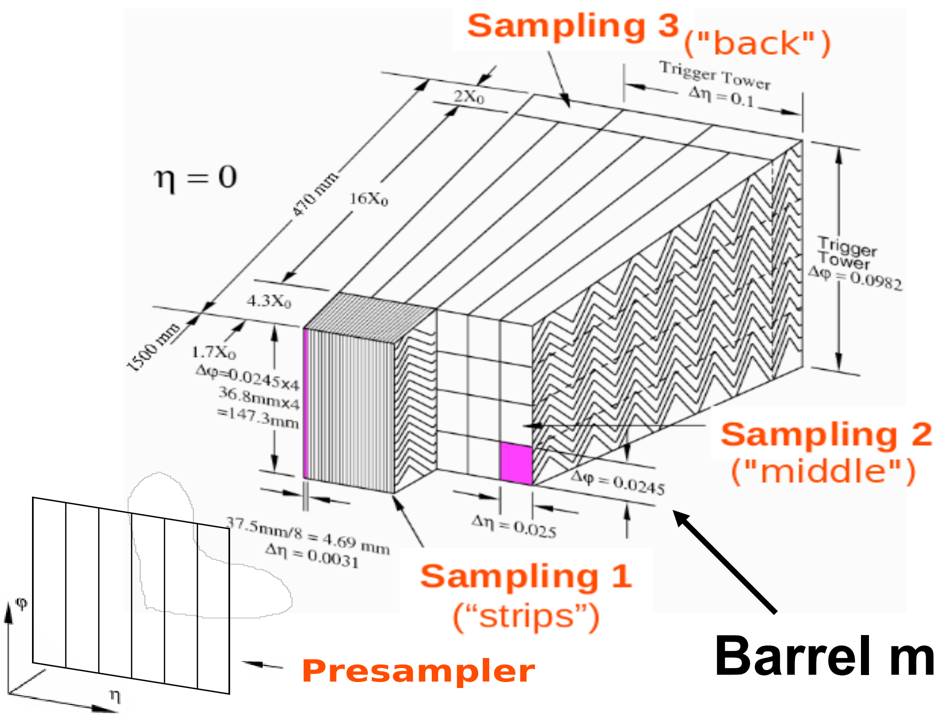
Transition Radiation Tracker (TRT)
- Axial barrel straws
- Radial end-cap straws
- Interleaved with polypropylene radiator
- ~35 straws per track
- (4 10^5 channels)
- electron PID capability

Total coverage $|\eta| < 2.5$

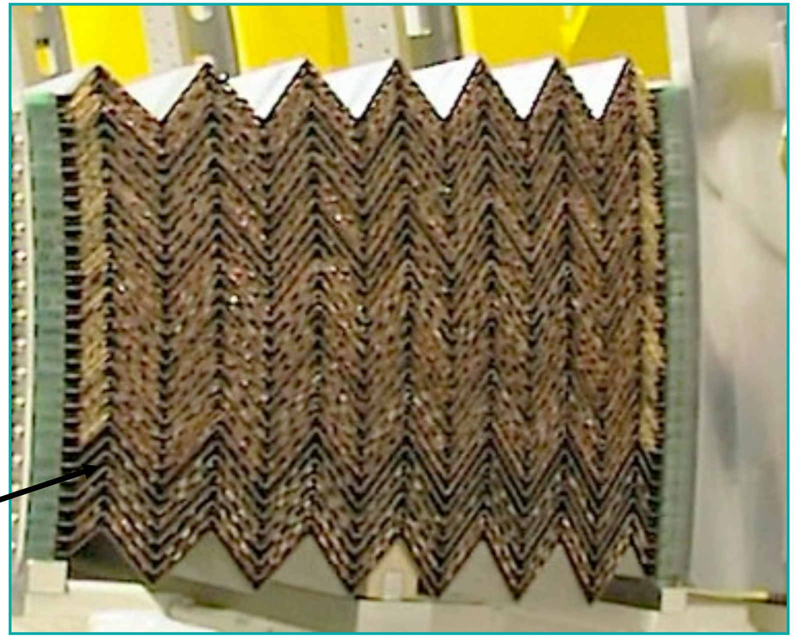




LAr EM Calorimeter description



Barrel module



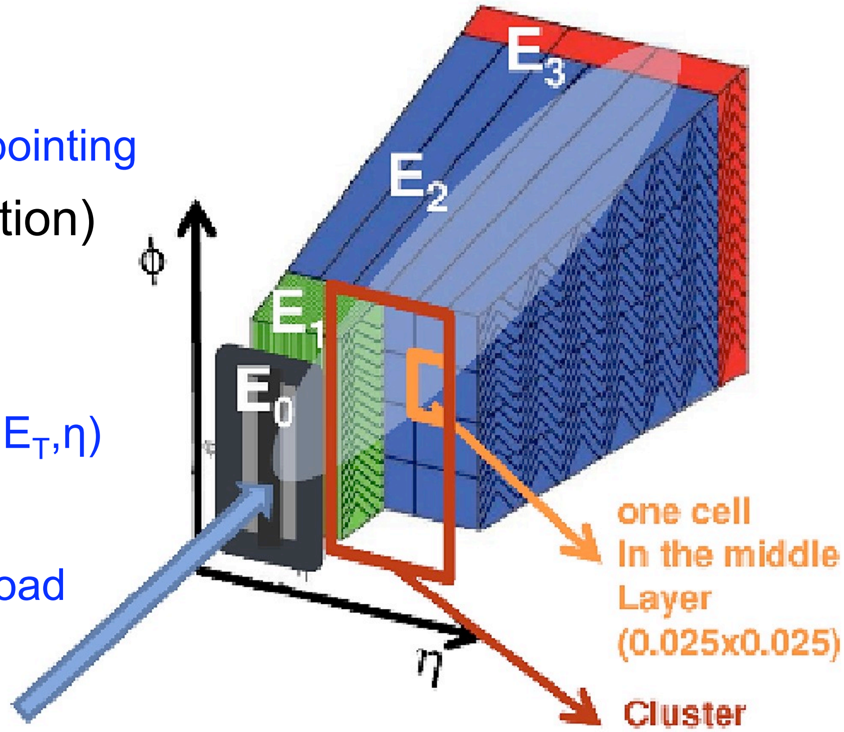
EM Calo (Presampler + 3 layers):

- **Presampler** 0.025×0.1 $(\eta\times\varphi)$
  $\Rightarrow$ Energy lost in upstream material
- **Strips** 0.003×0.1 $(\eta\times\varphi)$
  $\Rightarrow$ optimal separation of showers in non-bending plane, pointing
- **Middle** 0.025×0.025 $(\eta\times\varphi)$
  $\Rightarrow$ Cluster seeds
- **Back** 0.05×0.025 $(\eta\times\varphi)$
  $\Rightarrow$ Longitudinal leakage

- LAr-Pb sampling calorimeter
- Accordion shaped electrodes
- Fine longitudinal and transverse segmentation
- EM showers (for $e^{\pm}$ and photons) are reconstructed using calorimeter cell-clustering
- Total coverage $|\eta|<3.2$ (precision < 2.5)
- Fine segmentation in η: π^0 rejection

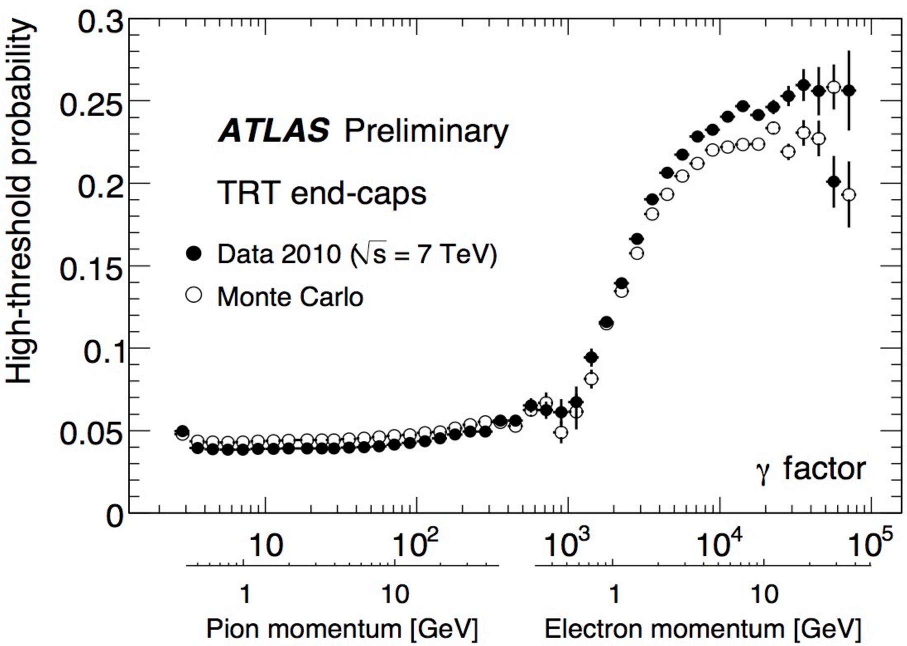
Electron/Photon Reconstruction in ATLAS

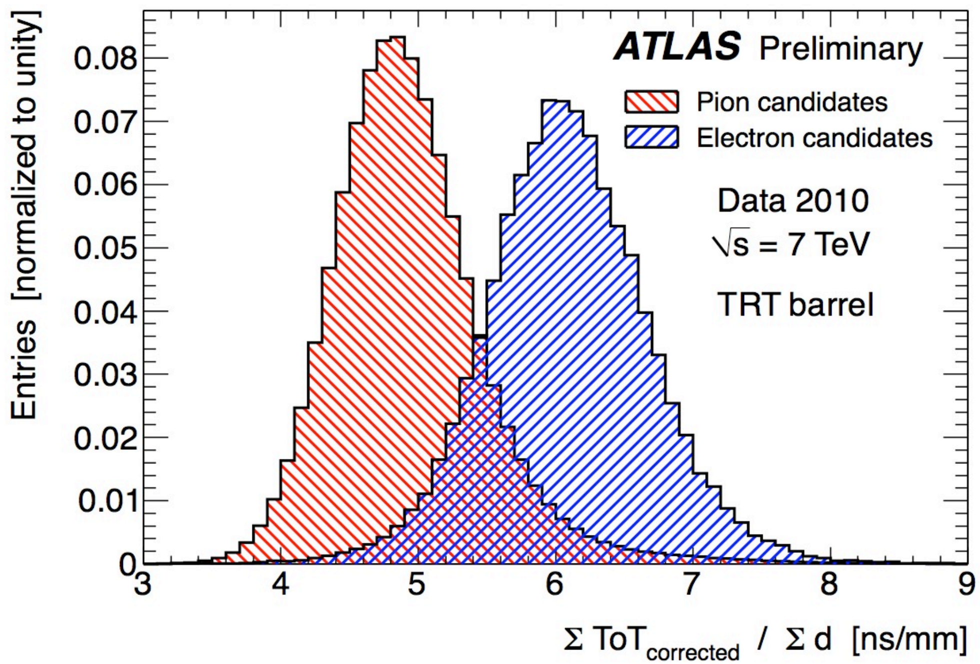
- Search for seed energy clusters in the EM calorimeter with significant energy
  - Seed clusters either rectangular window or result of nearest-neighbor clustering algorithm
- Match cluster with tracks/vertices. Classify as electron, unconverted/converted photon
  - Electron tracks corrected for bremsstrahlung losses
  - Photon conversion vertices formed by opposite charged electron tracks
- Form cluster from cells in a rectangular region around seed
  - Size depends on location and classification
- Calculate energy and direction
  - Energy weighted sum of layer energies
  - Corrected for detector effects
  - Direction provided by track information or cluster pointing
- Particle identification (hadronic background rejection)
  - Discriminating variables based on information from EM calorimeter, tracker, track-to-cluster matching (when applicable)
  - Define reference sets of cuts (optimized in bins of E_T,η)
    - Loose, medium, tight for electrons
    - Loose, tight for converted/unconverted photons
  - EM calorimeter shower shapes carry most of the load
  - Tight cuts result in highest signal purity
    - TRT particularly important at this stage



Electron Identification with TRT

- Transition radiation X-rays contribute significantly to the number of high threshold hits
  - True for electrons with energies above 2 GeV
  - Saturation sets in at electron energies above 10 GeV
- Including the Time over Threshold (ToT) could improve the rejection
  - Signal duration above threshold longer for electrons



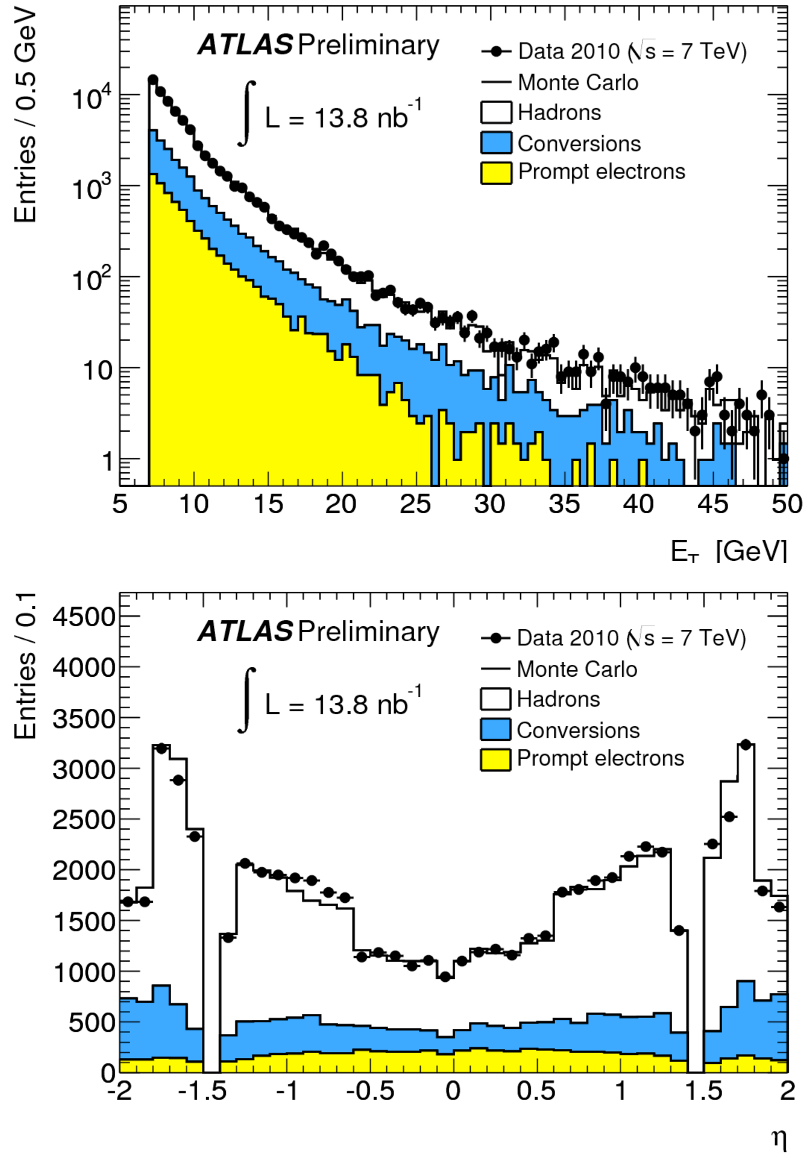


- Set up a likelihood evaluation based on information above (individual or combined)
- At higher energies pions become relativistic and start to emit transition radiation
  - TRT particle identification capabilities are reduced (minimal for pions above ~ 50GeV)
- Transition radiation performance in endcap TRT better than in the barrel

Inclusive Electron Analysis

Goal: Decompose E_T spectrum of electron candidates by origin
(b/c ⟶ e [Q], conversions [γ], hadrons [h])

(MC normalized to data)



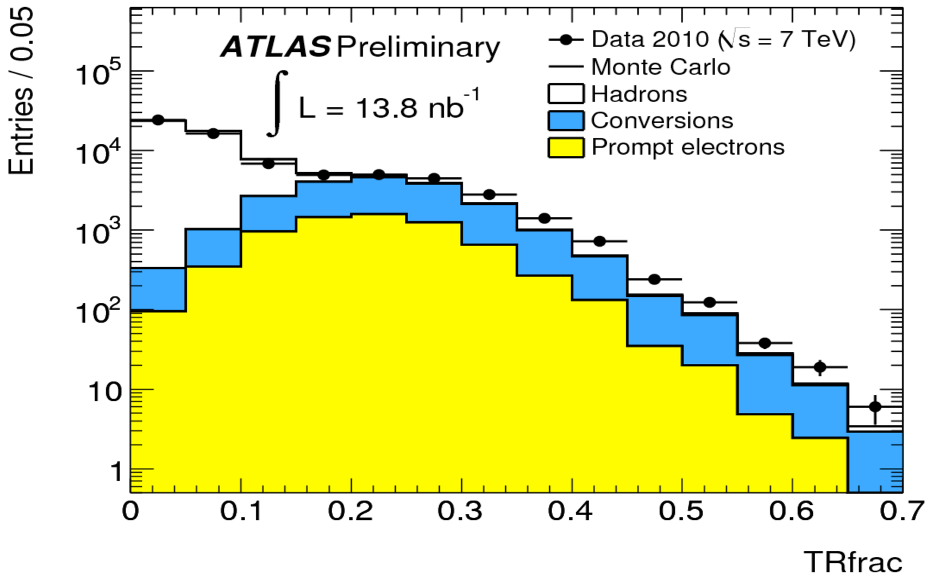
Candidate selection variables:

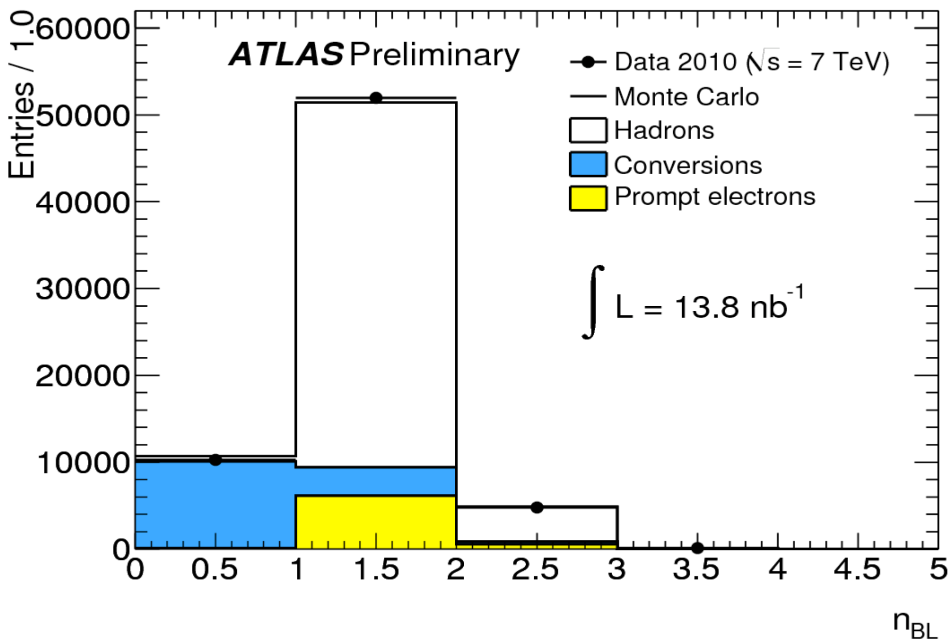
- E_T>7 GeV; |η|<2.0; exclude cracks between calorimeters
- f_1: Fractional energy in layer 1
  - Hadrons characterized by lower f_1 values
- Shower width + shape in layer 1
  - Smaller and more uniform for electrons
- Number of hits in tracking detectors
  - Smaller for conversion electrons
- Track transverse impact parameter with respect to primary vertex
  - Larger for conversion electrons
- Δη (track,cluster)
  - Larger for hadrons

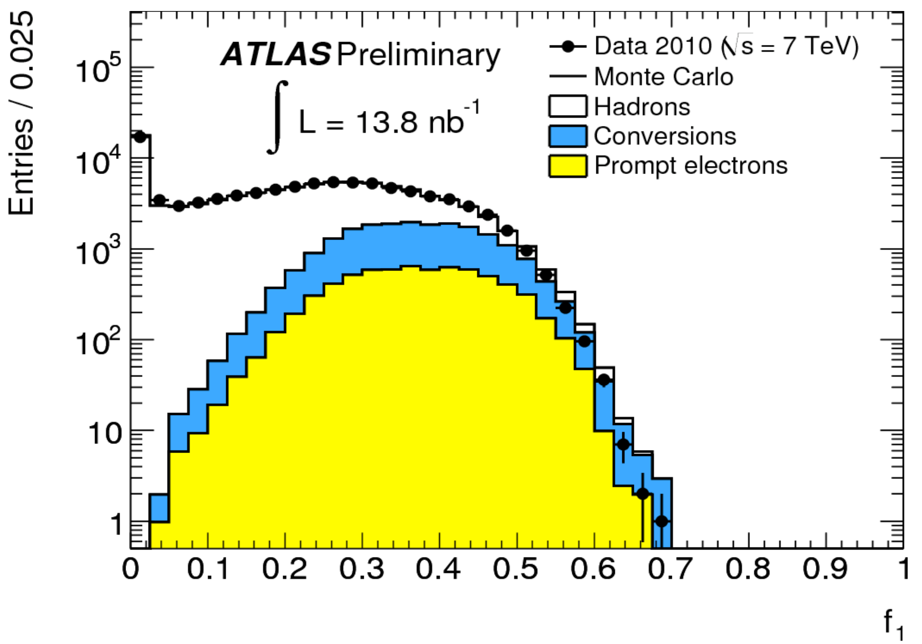
Electron Discriminating Variables

Need variables to discriminate between the different candidate sources

- Electrons vs hadrons
  - f_{TR}: Fraction of high threshold TR hits
  - f_1: Energy fraction in layer 1
- Prompt electrons vs. conversions
  - n_{BL}: Number of innermost (B) pixel layer hits







Matrix Method to Extract Components

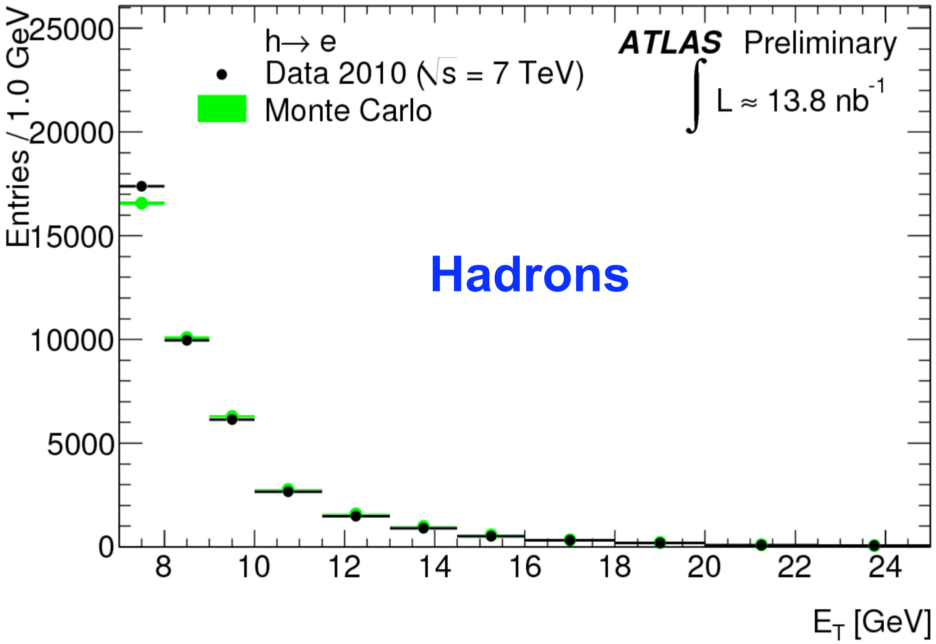
Extract the three components by using the "matrix" method

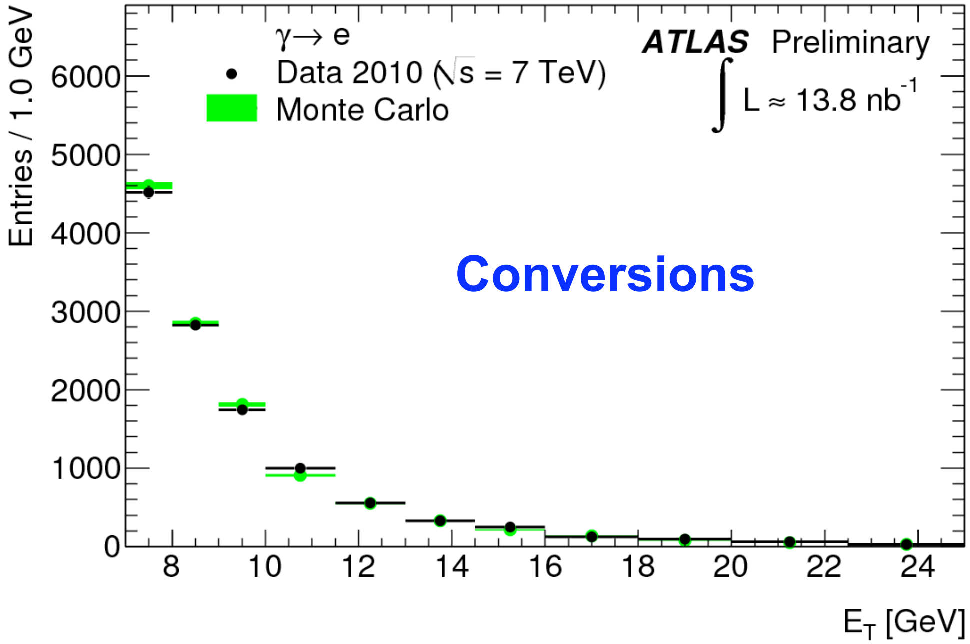
- Distribute electron candidates in bins of two uncorrelated variables: f_{TR} and n_{BL}
- Within each bin:
  - N, N_{TR}, $N_{TR,BL}$ are events passing cuts for this bin
  - $\varepsilon^h,\varepsilon^\gamma,\varepsilon^Q$ the efficiencies for hadrons/conversions/electrons to pass
- Extract number of each component candidates by solving set of three equations

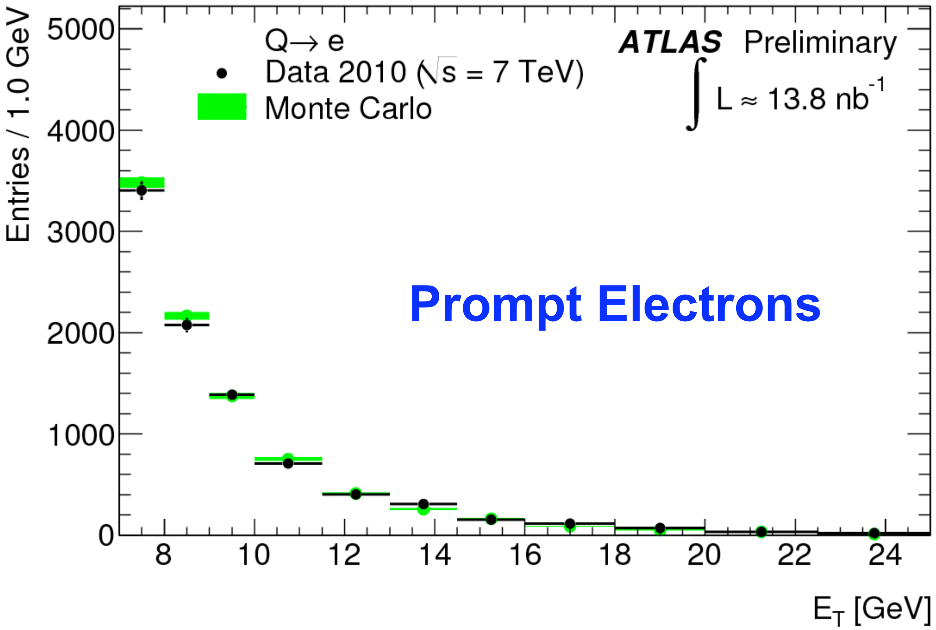
$$\begin{pmatrix} N \\ N_{TR} \\ N_{TR,BL} \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 \\ \varepsilon^h{}_{TR} & \varepsilon^\gamma{}_{TR} & \varepsilon^Q{}_{TR} \\ \varepsilon^h{}_{TR,BL} & \varepsilon^\gamma{}_{TR,BL} & \varepsilon^Q{}_{TR,BL} \end{pmatrix} \begin{pmatrix} N^h \\ N^\gamma \\ N^Q \end{pmatrix}$$

- ε^γ, ε^Q from Monte Carlo
- ε^h from a hadron data sample obtained by inverting f_1
- Events binned in η/p; method carried out separately for each bin
- Can be used to obtain the distribution for each component of any variable independent of f_{TR}, n_{BL}

Component Extraction Results







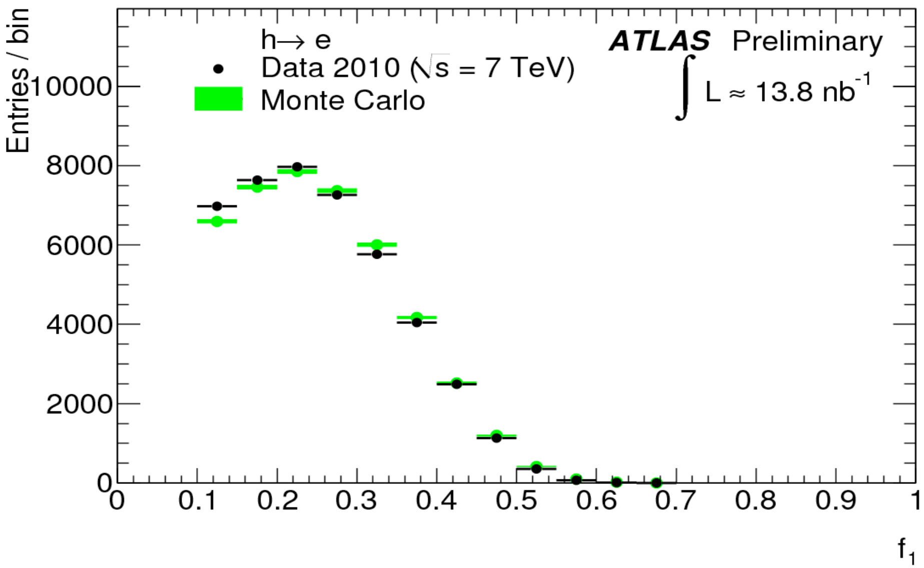
Numbers of extracted events

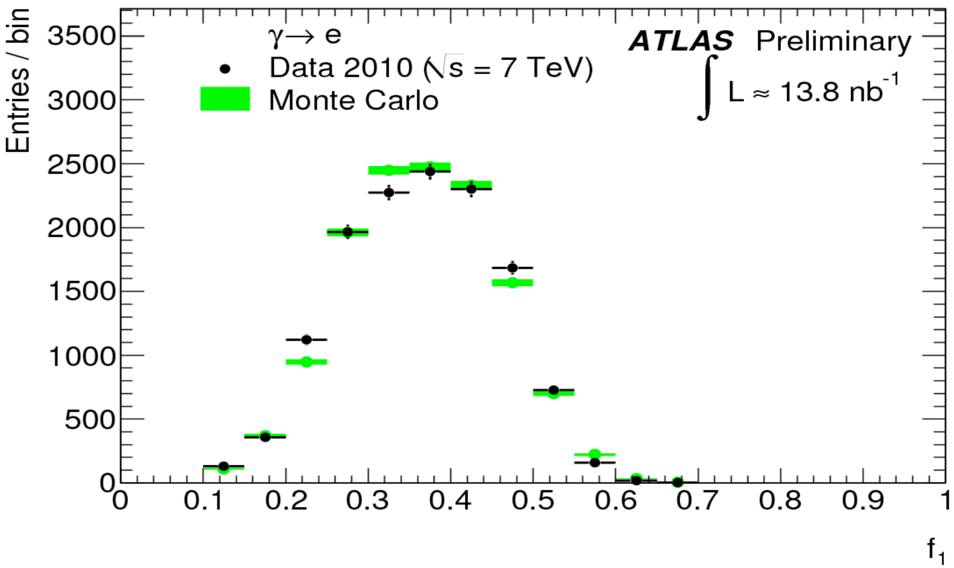
	Data	MC
h	43470±240	46730±150
γ	13160±150	13580±80
Q	9920±160	6890±60
Total	67124	

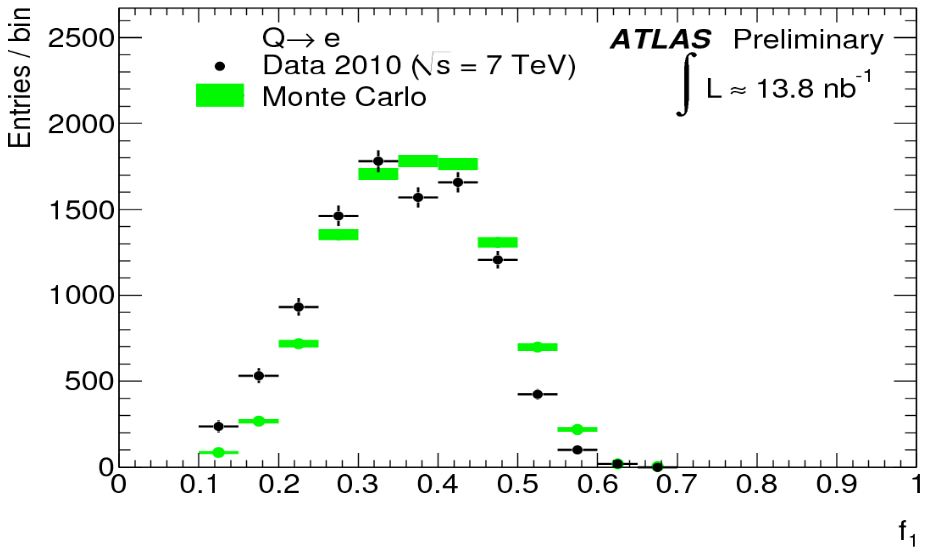
(Statistical errors only)

Identification Variable Distribution

- Use the matrix method to obtain the distribution of an identification variable independent of f_{TR}, n_{BL} used for extracting the signal components
- Important method cross-check:
  - Compare derived distribution to MC prediction







Example: f_1 distribution

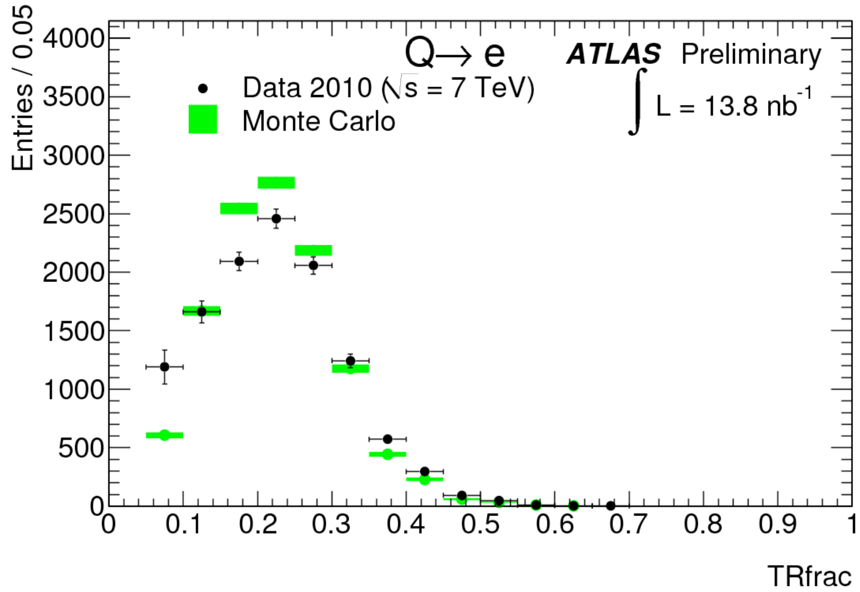
(MC plots normalized to data)

Systematic Uncertainties

Source	ΔN/N
Method	±0.9%
Hadron Discrimination	±3.3%
ε^{Q}_{TR}	±5.4%
$\varepsilon^{\gamma}_{BL}$	±6.6%
Other ε	<1%
MC Statistics	±1.2%
Binning	±1.5%
EM Energy Scale	<0.5%

Use f_1 instead of f_{TR} to extract components:

- Replace by orthogonal cut on $f_{TR}>0.05$
- Extract components with matrix method



Cross-check matrix method by using two-dimensional extended maximum likelihood fit:

- Use binned two-dimensional PDFs based on f_{TR} and n_{BL}
- Perform fit in bins of η/p as for the matrix method
- Obtain components by summing results across all η,p bins

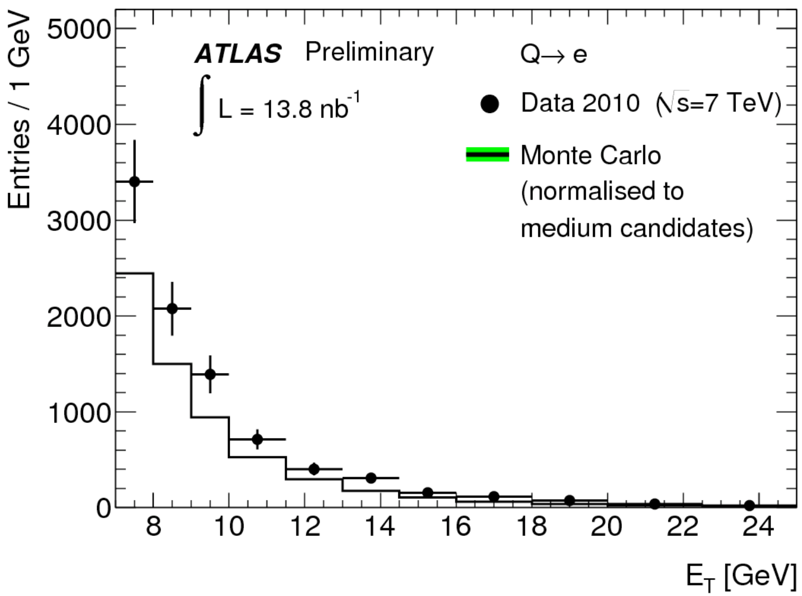
Component	$h \rightarrow e$		$\gamma \rightarrow e$		$Q \rightarrow e$	
Method	Matrix	Likelihood	Matrix	Likelihood	Matrix	Likelihood
Electron cand. fraction	65.2±0.4	65.4±0.3	19.8±0.2	19.4±0.2	15.0±0.2	15.2±0.2

Comparison to Monte Carlo

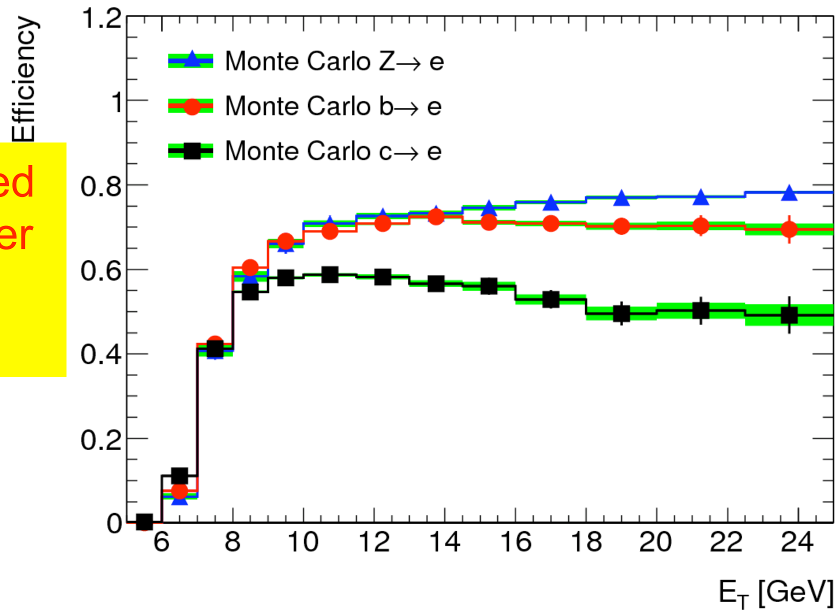
Observed prompt electron signal: 9920 ± 160 (stat.) ± 990 (syst.)

Compare to predictions from LO parton shower simulations using Pythia 6.4:

- Generate heavy flavored filtered minimum bias samples:
  - Require at least one b(c) quark present in final hard-scattering state
  - At least one electron with E_T>3GeV and $|\eta|$<2.7 produced in the event
  - Remove overlap by excluding electrons from the c sample with a b-quark present within the acceptance



MC normalized to total number of electron candidates



- Differences to the predicted rates from MC and data due to:
  - Uncertainties in cross-sections of backgrounds to prompt electron signals
  - Uncertainties in heavy flavor cross-section itself
  - Uncertainties in efficiencies for identifying non-isolated electrons
- Efficiencies lower than those for observing isolated W/Z electrons
- Efficiency for c-quark electrons lower than b-quark ones since less isolated

Inclusive Electrons with Tighter Selection

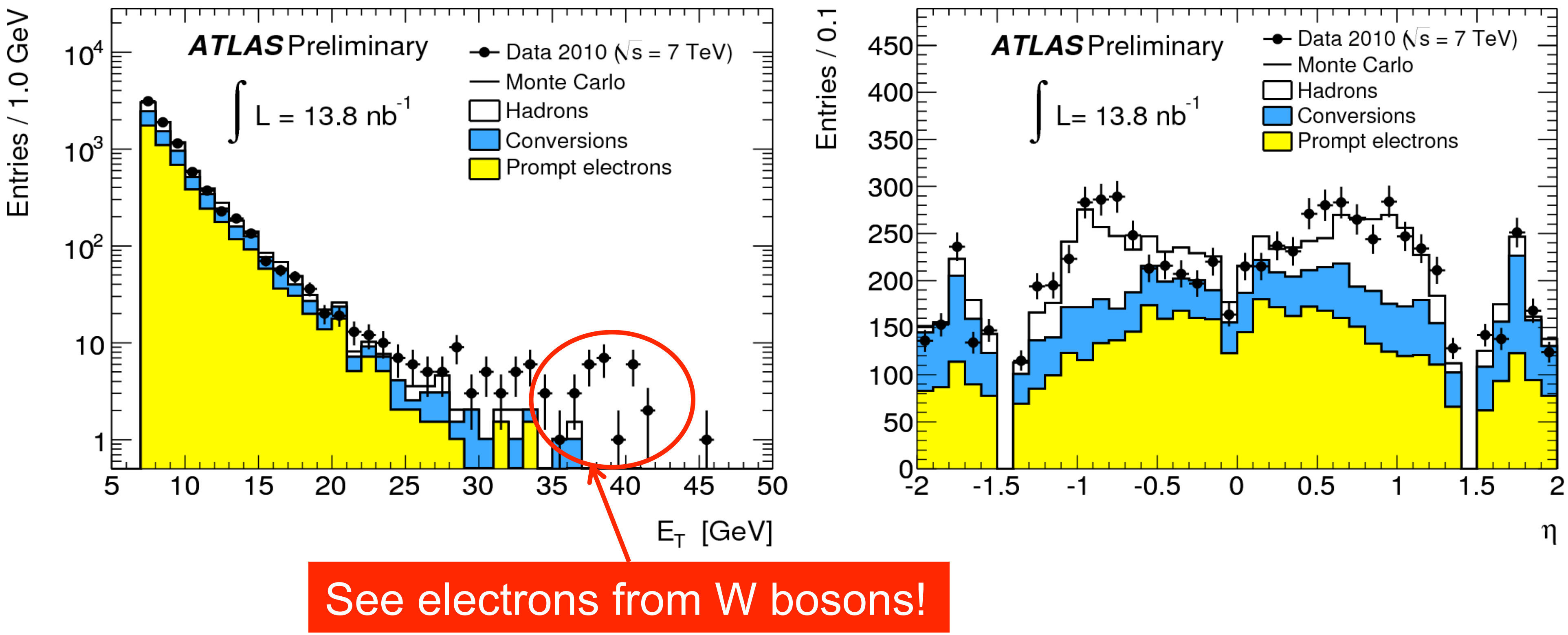
Additional selection variables:

- Hadronic leakage
  - Should be small
- $R_\eta = E(3\times7)/E(7\times7)$
  - Should be large
- Cluster/track E/p
  - Should be close to 1
- n_{BL} and f_{TR}

Measured 8024 candidates in 13.8 nb^{-1}

Expect:

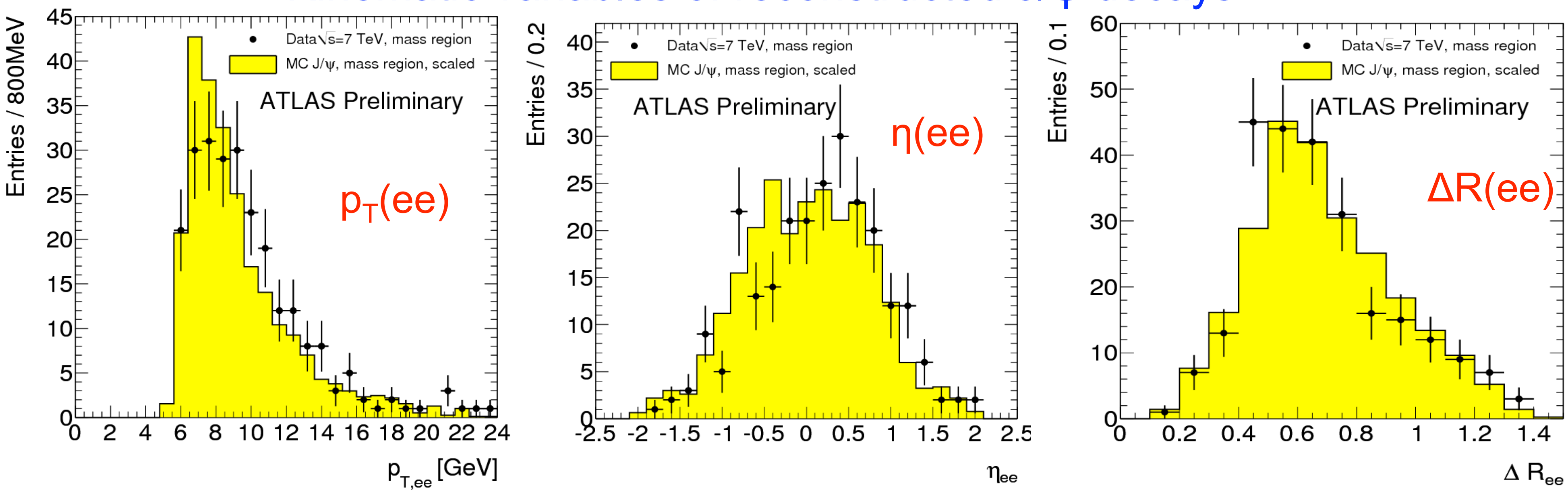
- 59% prompt electrons
- 23% conversion electrons
- 18% hadrons



Reconstruction of $J/\psi \rightarrow e^+e^-$

- Use integrated luminosity of 77.8 nb^{-1}
- Candidate cluster seeded with nearest neighbor clusters
  - Increases reconstruction efficiency by factor of 2 for low p_T electrons
- Take opposite sign pairs of electrons candidates, one with p_T>4 GeV and one with p_T>2 GeV
- Electron candidate selection:
  - Use R_η, f_1, shower shape in layer 1
  - Track impact parameter (tracks compatible with emerging from primary vertex)
  - Number of silicon tracker hits (compatible with track through full length of Si-tracker)
  - Strict requirement on high-threshold hit fraction f_{TR} from TRT

Kinematic variables of reconstructed J/ψ decays



MC includes J/ψ only; no b-mesons

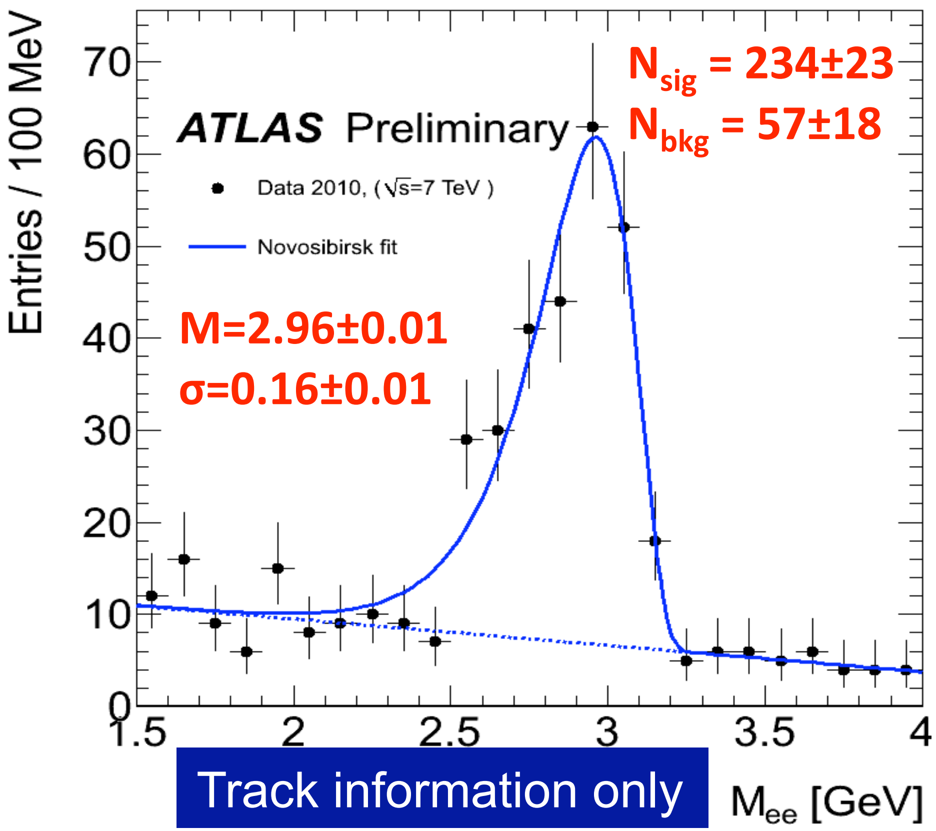
J/ψ Invariant Mass Reconstruction

- Reconstruct the invariant mass using tracking information only
  - Fit peak using the Novosibirsk function

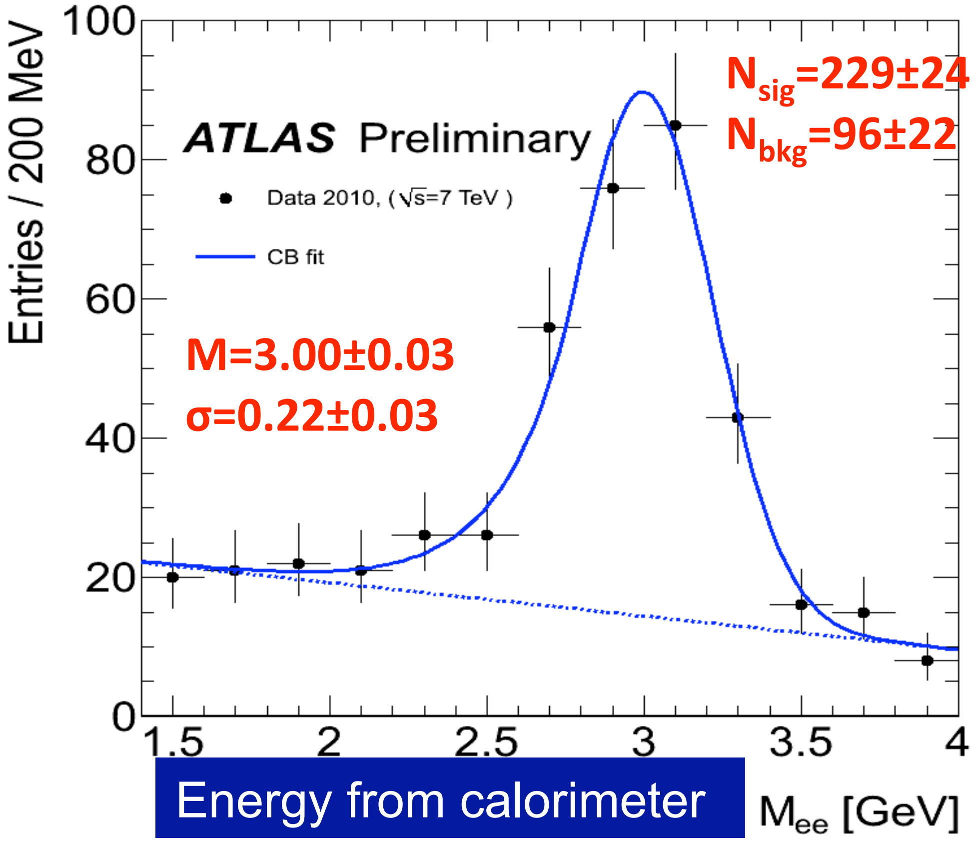
$$f(m) = A_S \ \exp(-0.5 \ln^2[1+\Lambda\tau (m-m_0)]/\tau^2 + \tau^2)$$

where $\Lambda=\sinh(\tau\sqrt{\ln 4})/(\sigma\tau\sqrt{\ln 4})$, m_0 peak position, σ width, τ tail parameter
  - Mean smaller than known J/ψ mass due to bremsstrahlung tail

- Repeat using energy from EM clusters, direction from tracking
  - Fit peak using the Crystal Ball function
  - Mean smaller than known J/ψ mass due to imperfect calorimeter calibration at low p_T



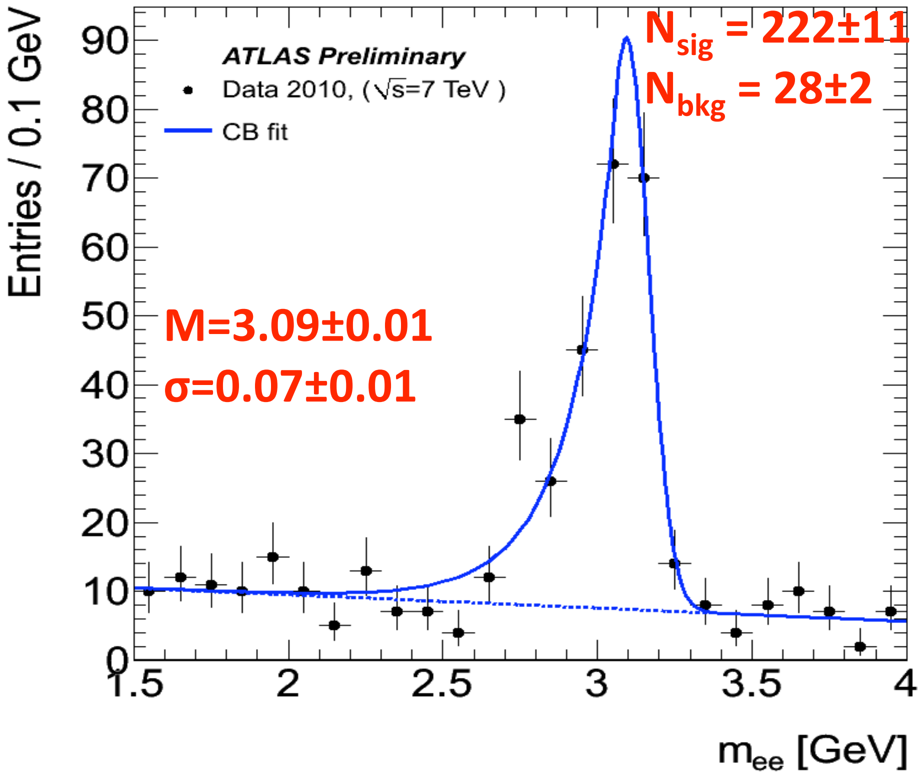
Track information only

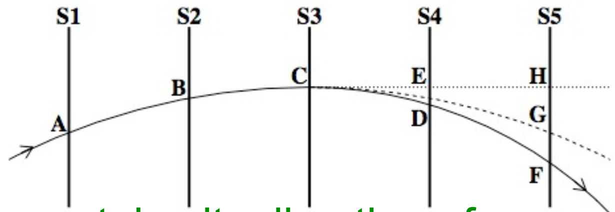


Energy from calorimeter

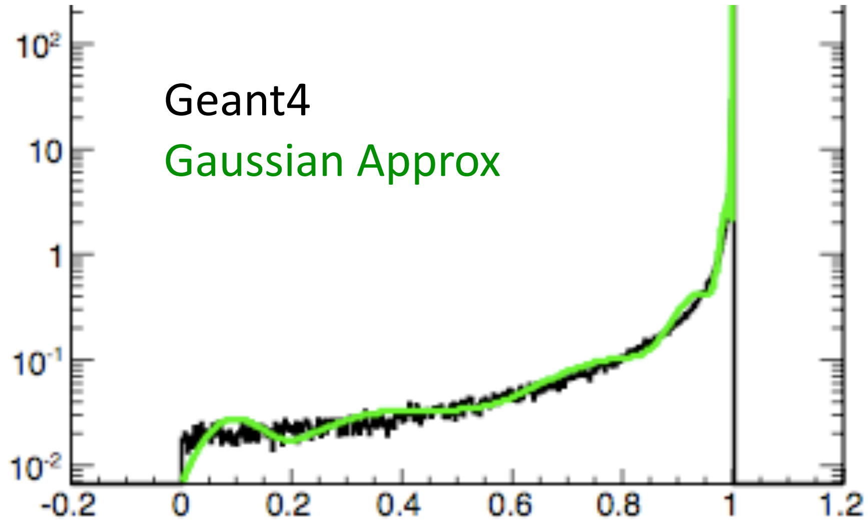
Bremsstrahlung Correction

- Use track information only after refitting tracks to account from bremsstrahlung losses:
  - Energy loss described by Bethe-Heitler distribution
  - Use Gaussian Sum Filter[1] to approximate it with sum of Gaussian distributions
  - Takes into account the asymmetry and low-energy tail of distribution
  - Fit mass peak using a Crystal Ball function
  - Mass resolution improves by more than a factor of 2





Electron retains its direction of propagation



PDG average m(J/ψ) = 3.097 GeV

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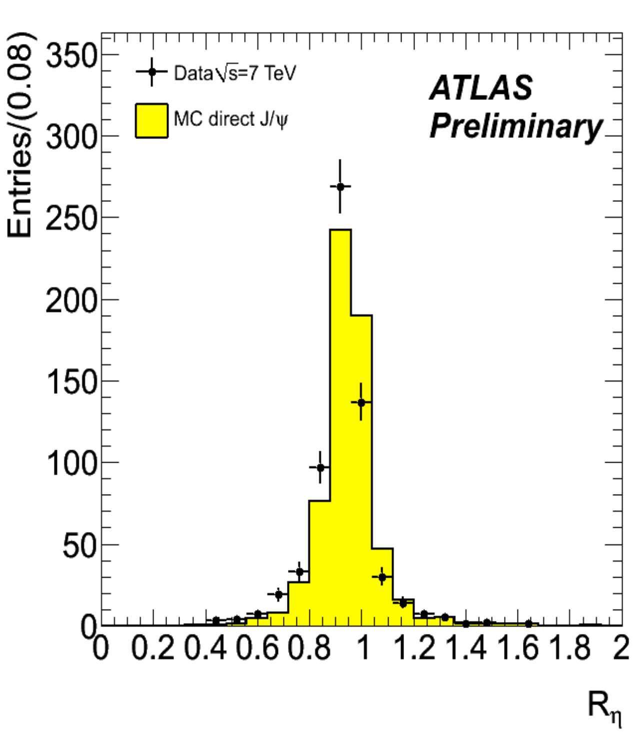
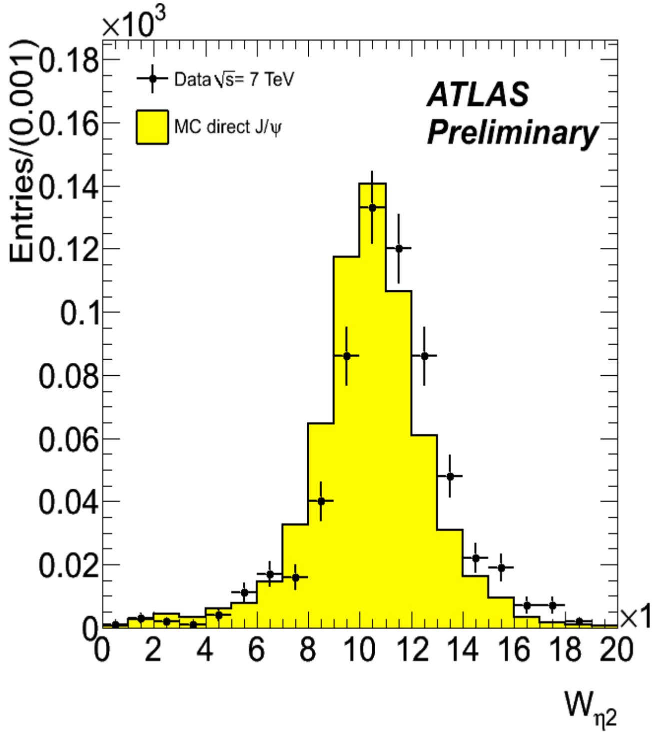
[1] R. Frühwirth, Comp. Phys. Comm. **100** (97); T. Atkinson, PhD Thesis, U. Melbourne (06)

Shower Shapes of J/ψ Electrons

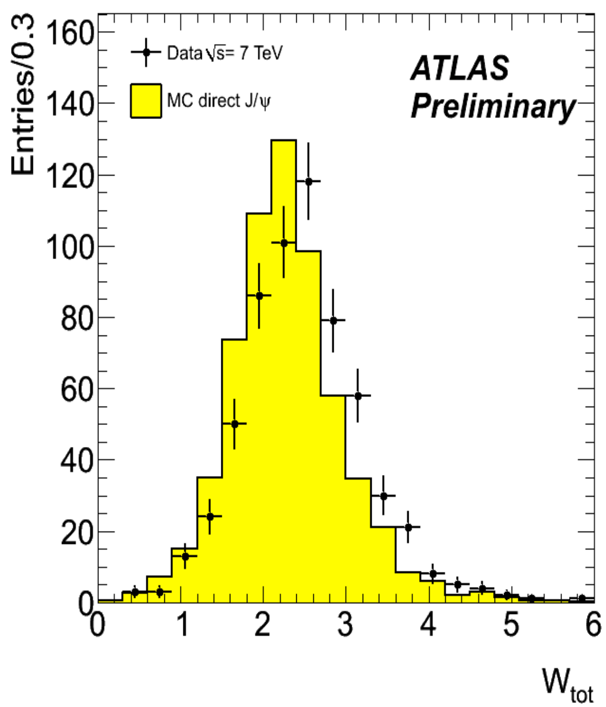
- The J/ψ signal provides a sample of real electrons that can be used to check the modeling of electron discriminating variables by the detector simulation
  - Important for evaluating systematic uncertainties on electron identification
- Use a tag&probe approach:
  - Maintain tight selection on the tag electron (p_T>4 GeV, cluster E_T>2.5 GeV, f_{TR}>0.18)
  - Remove shower shape selection criteria from the other probe electron
- Select electron pair candidates with 2.7 GeV < m_{ee} < 3.2 GeV
- Small systematic differences between data and MC are becoming visible



R_η=E(3×7)/E(7×7)



Cluster η width: Layer 2



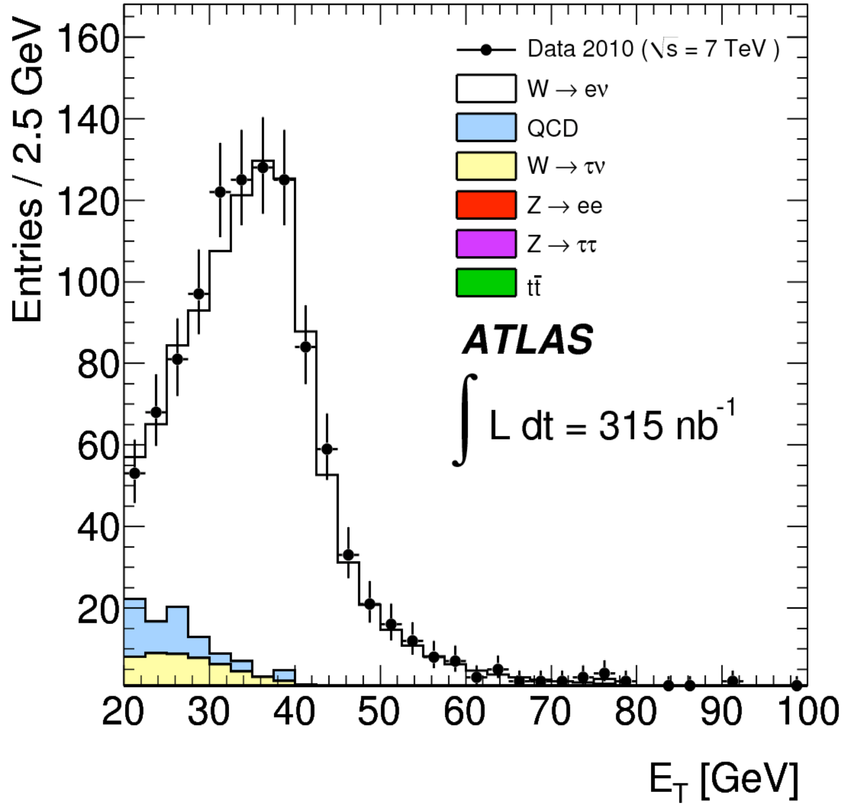
Cluster η width: Layer 1

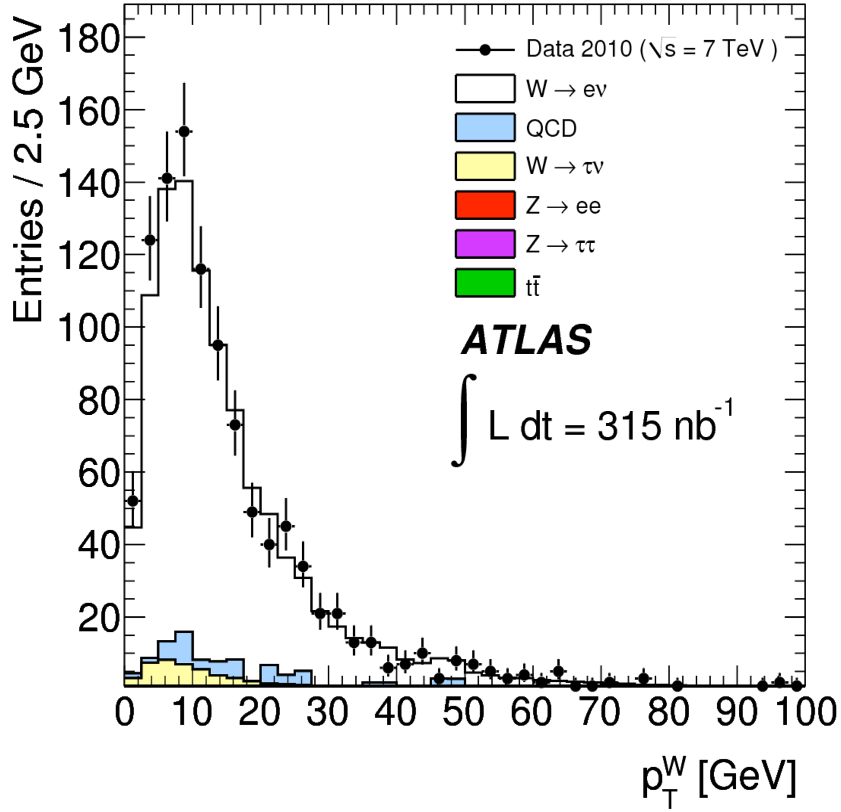
W⟶eν Reconstruction

Kinematic selection:

- "Tight" electron with E_T > 20GeV
- Missing transverse energy E_T^{miss} > 25GeV
  - Baseline estimation from calorimeter clusters corrected to hadron energy scale
- Transverse mass of the lepton-E_T^{miss} system m_T > 40GeV
  - Defined as: $$m_T = \sqrt{2\, p_T^{\ell} p_T^{\nu} (1 - \cos(\phi^{\ell} - \phi^{\nu}))}$$

1069 W⟶eν candidates (637 e^+, 432 e^-)





W⟶eν Cross-Section $\int\mathcal{L}$=315 nb^{-1}

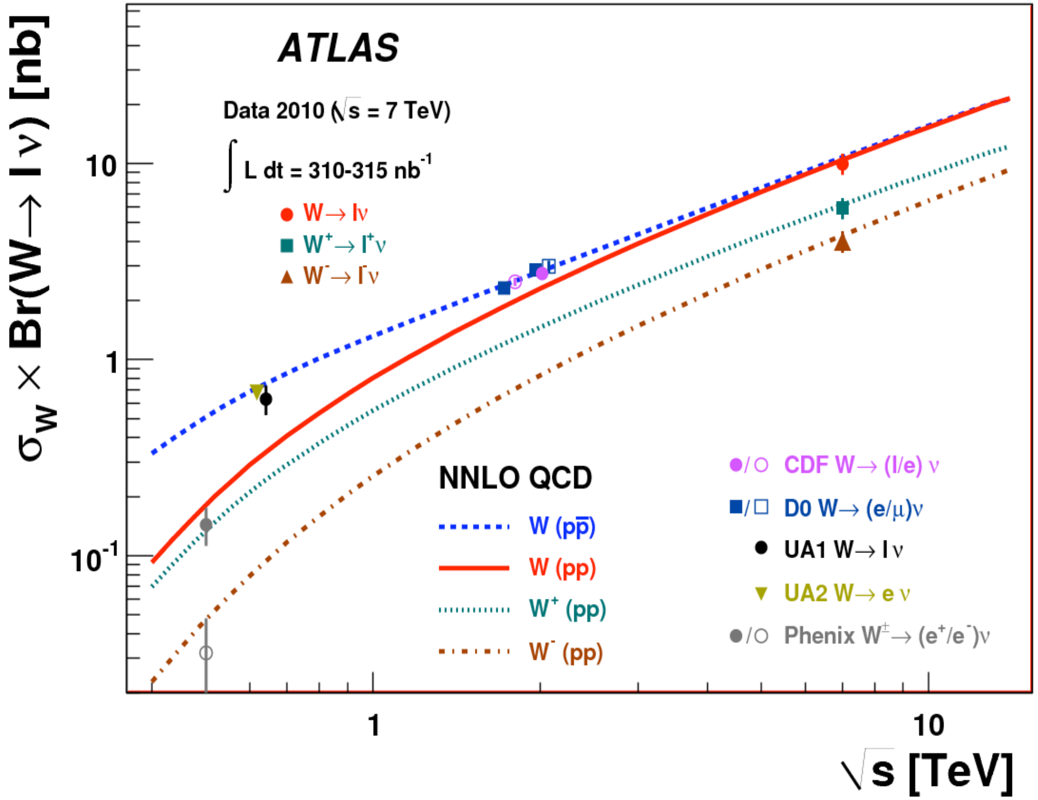
$$\sigma = \frac{N_{\text{cand}} - N_{\text{background}}}{A_W \times C_W \times \int \mathcal{L}\, dt}$$

where:

- A_W, acceptance factor determined by phase-space requirements in the analysis
- C_W, correction factor due to reconstruction efficiency, triggering, W-identification

- **$\sigma(W^{\pm}\to e^{\pm}\nu_e)$ = 10.51±0.34(stat)±0.81(syst)±1.16(lumi) nb**

Systematic uncertainties on C_W ~7%:
  - Electron reconstruction efficiency
  - Material effects
  - Electron energy scale and efficiency
- Systematic uncertainties on A_W ~3%:
  - Limited knowledge of proton PDFs
  - W-production modeling at the LHC
- Luminosity estimate uncertainty at 11%

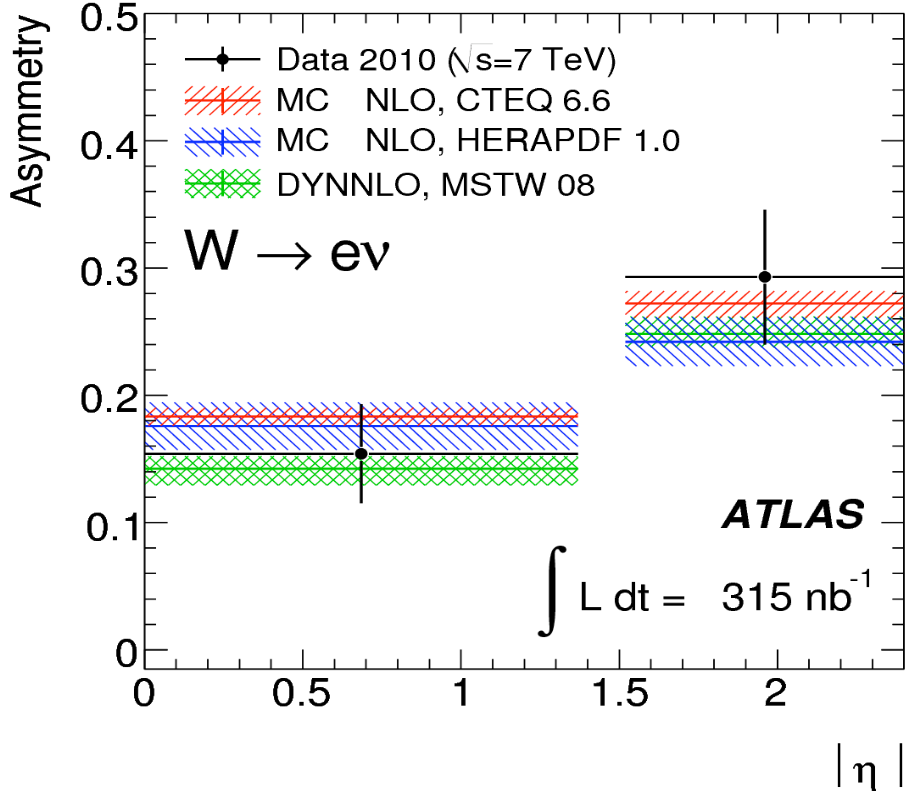


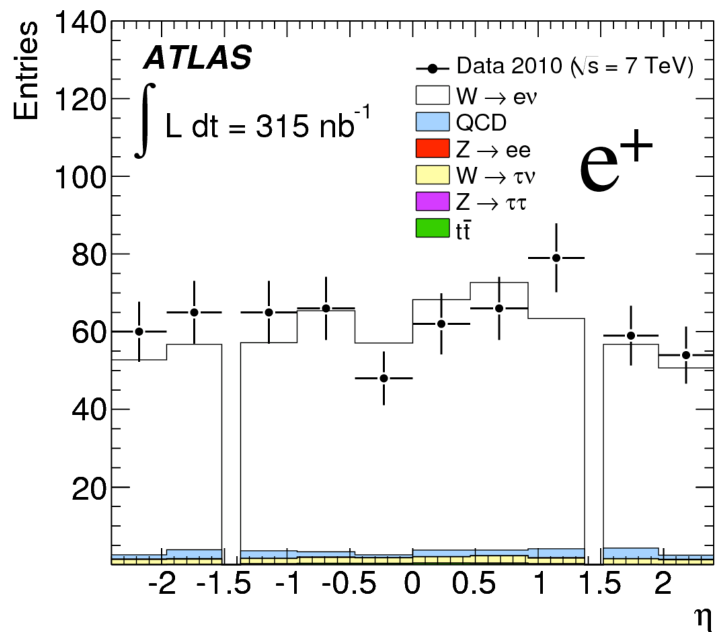
W→eν Charge Asymmetry

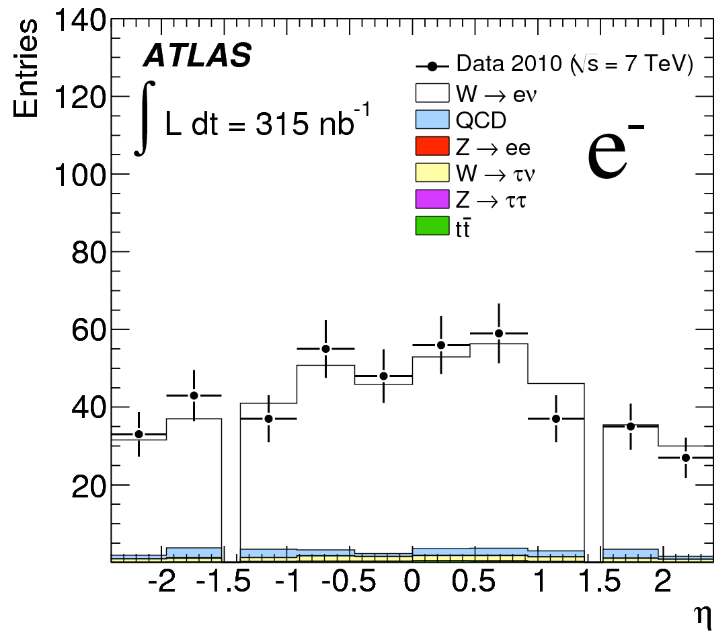
- Can provide important information about PDFs
- Defined as:

$$A = \frac{\sigma^{\ell^+} - \sigma^{\ell^-}}{\sigma^{\ell^+} + \sigma^{\ell^-}}$$

- Asymmetry depends on pseudorapidity
  - Probe different parton momentum fractions x
- Asymmetry reflects the fact that N_u = ~2×N_d
  - W^+ production favored in p-p collisions
- W-lepton asymmetry sensitive to valence quarks





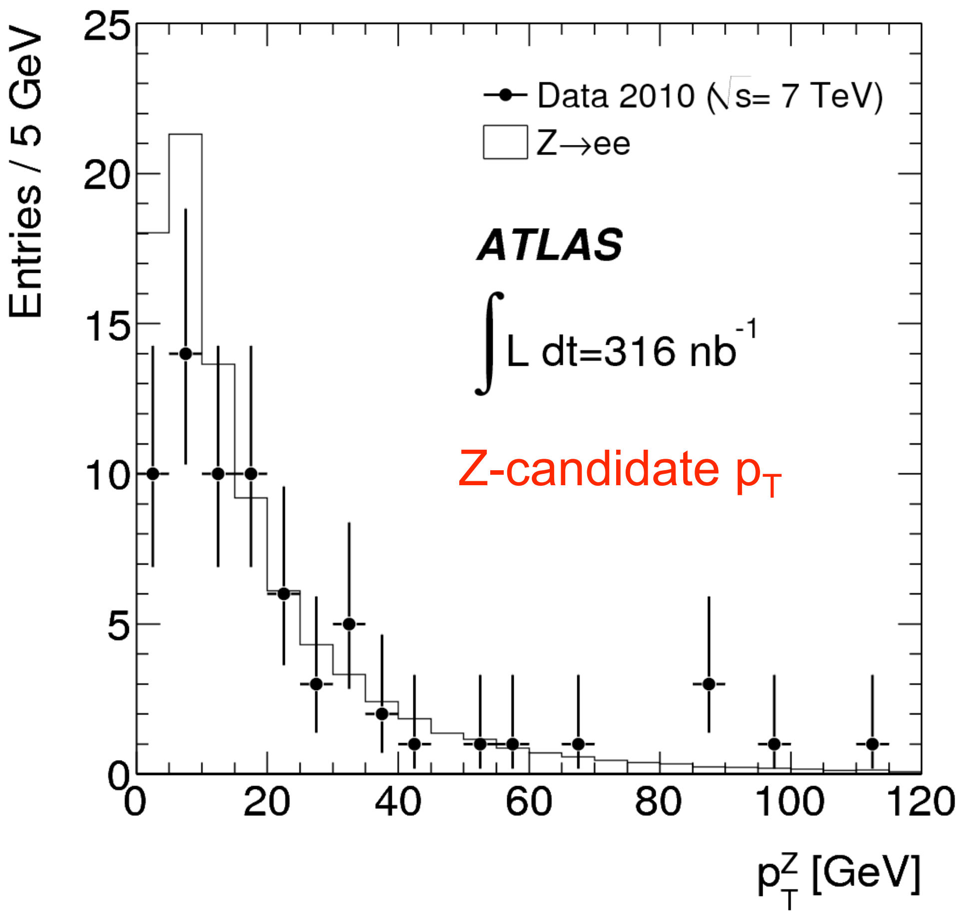


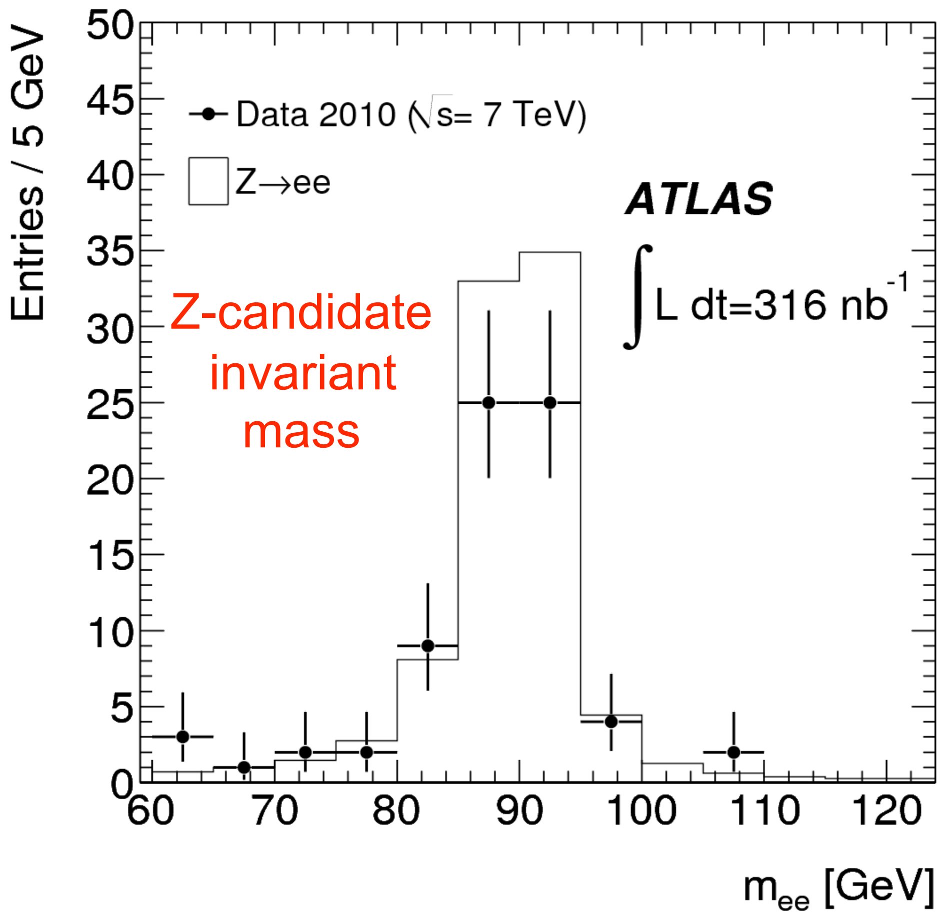
$Z \longrightarrow ee$ Reconstruction

Kinematic selection:

- Pair of oppositely charged electrons
- Invariant mass window: $66 < m_{ee} < 116$ GeV
- Veto events with ≥3 "medium" electrons

70 $Z \longrightarrow ee$ candidates





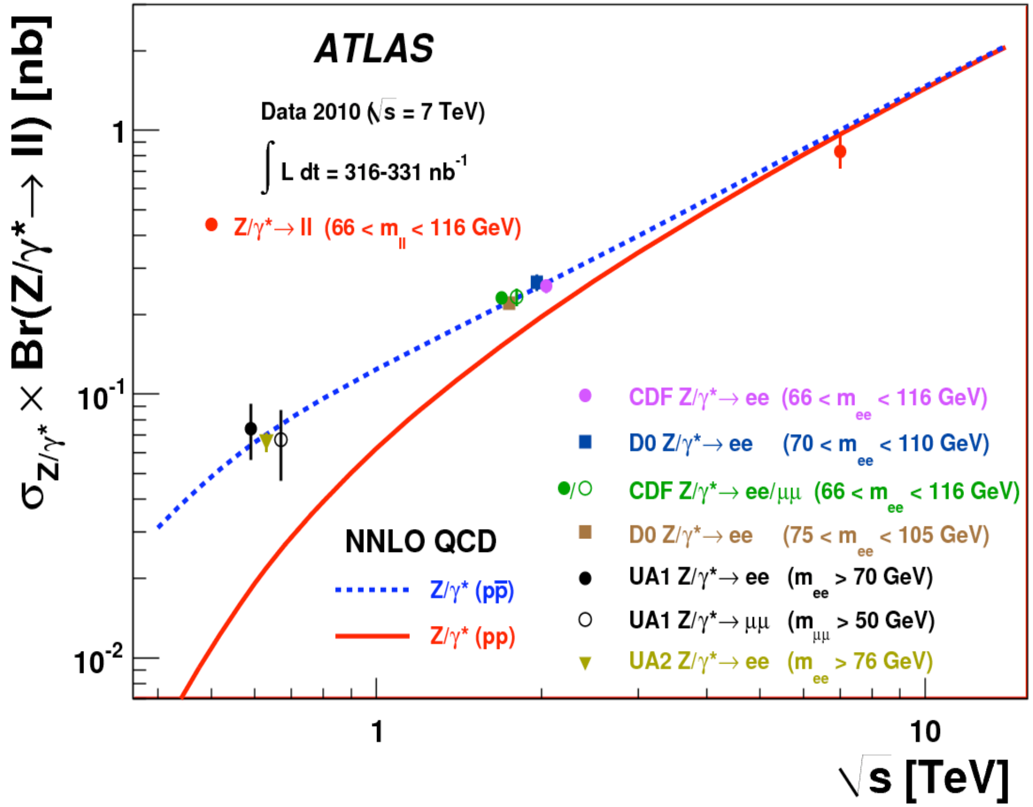
Z⟶ee Cross-Section $\int\mathcal{L}$=331 nb^{-1}

$$\sigma = \frac{N_{\text{cand}} - N_{\text{background}}}{A_W \times C_W \times \int \mathcal{L}\, dt}$$

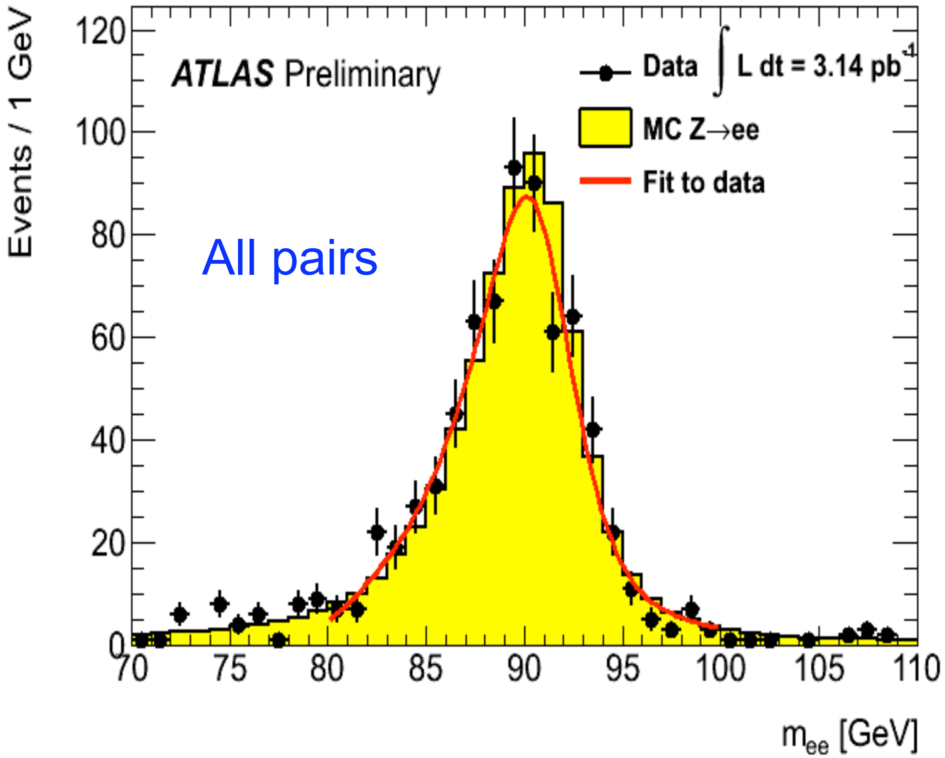
- $\sigma(Z\rightarrow e^+e^-)=0.75\pm0.09(\text{stat})\pm0.08(\text{syst})\pm0.08(\text{lumi})$ nb

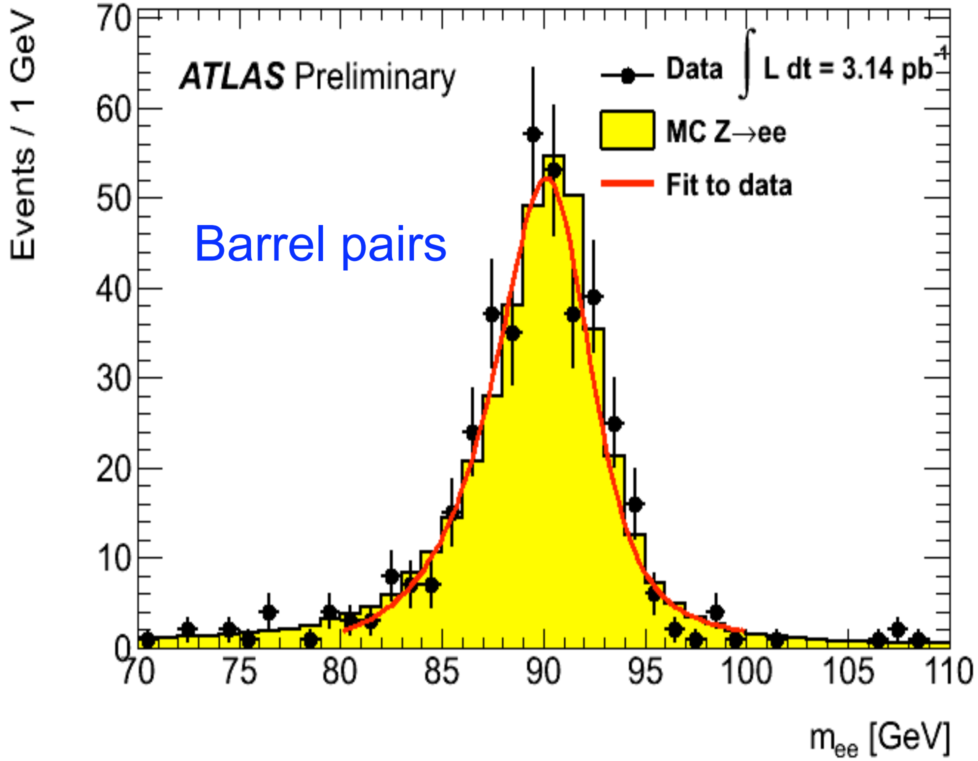
Systematic uncertainties on C_W ~9.4%:
- Electron reconstruction efficiency
- Material effects
- Electron energy scale and efficiency

- Systematic uncertainties on A_W ~4%:
  - Limited knowledge of proton PDFs
  - Z-production modeling at the LHC
- Luminosity estimate uncertainty at 11%



Calibrated Z⟶ee Invariant Mass



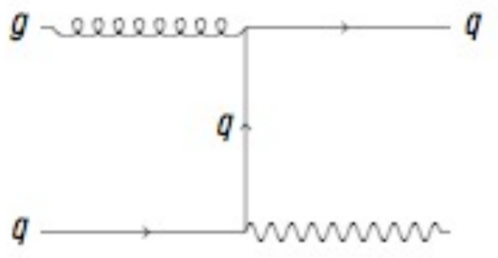


- EM energy scale can be set by constraining the di-electron invariant mass to follow the well known Z line shape
  - Corrections -0.97±0.16% in barrel, 2.06±0.46%(1.70±0.50%) in $\eta>0$($\eta<0$) end-caps
- Calibrated Z-mass resolutions:
  - 1.59±0.04(stat.) GeV (1.40±0.01(stat.)) in data(MC) for all di-electron candidates
  - 1.51±0.05(stat.) GeV (1.29±0.02(stat.)) in data(MC) for barrel-barrel candidates

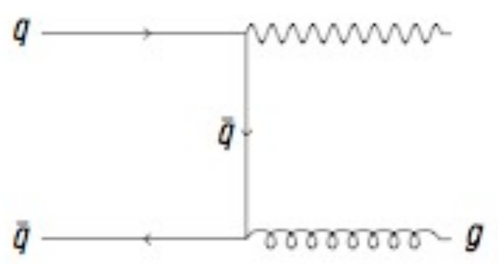
Direct Photon Reconstruction

Why direct photons?

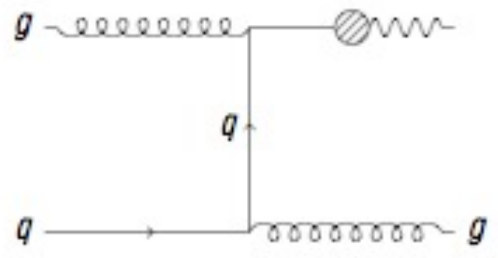
- One of the first measurements in ATLAS that identifies/uses photons:
  - No clean source of photons like the electrons
  - Requires a good understanding of the detector
- Provide a clean probe of the gluon composition of the proton
  - A QCD measurement without jets
- Single- and di-photons are important components of some SM/BSM analyses:
  - $H \longrightarrow \gamma\gamma$ will be important for low mass Higgs
  - GMSB in SUSY
  - Graviton searches, high-mass di-photon resonances



Compton scattering



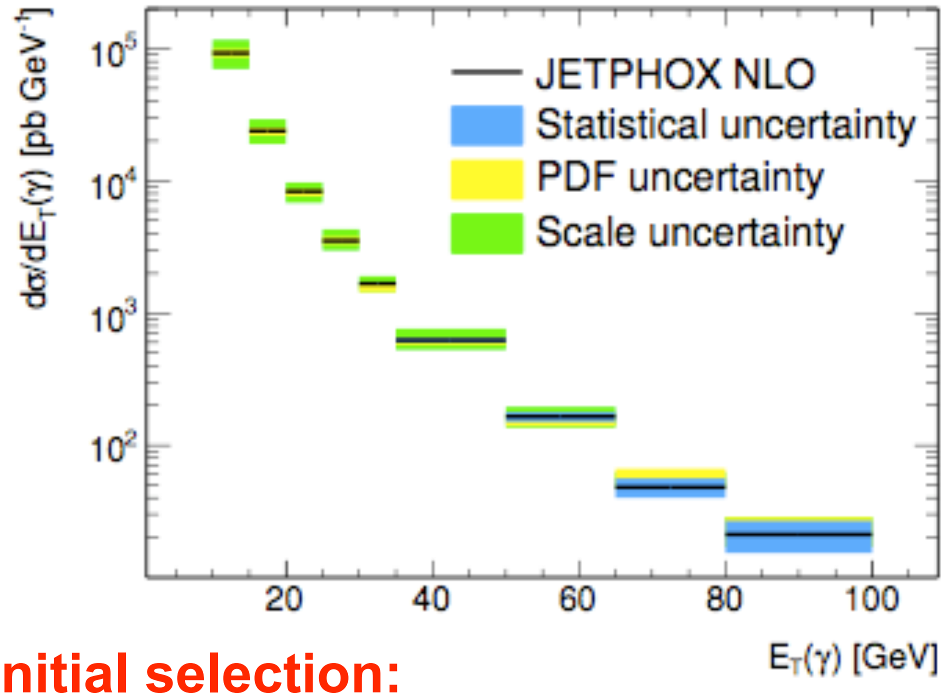
Quark annihilation



Fragmentation

- Signal is composed of “direct” and “fragmentation” processes:
  - Direct part is dominated by Compton process at LHC
  - Fragmentation part more significant at low E_T
  - Reduce QCD background by imposing isolation requirement
- Primary background is from real photons (e.g. $\pi^0 \longrightarrow \gamma\gamma$)

Direct Photon Spectrum



Expected direct photon cross-section using NLO QCD computation as implemented in JETPHOX

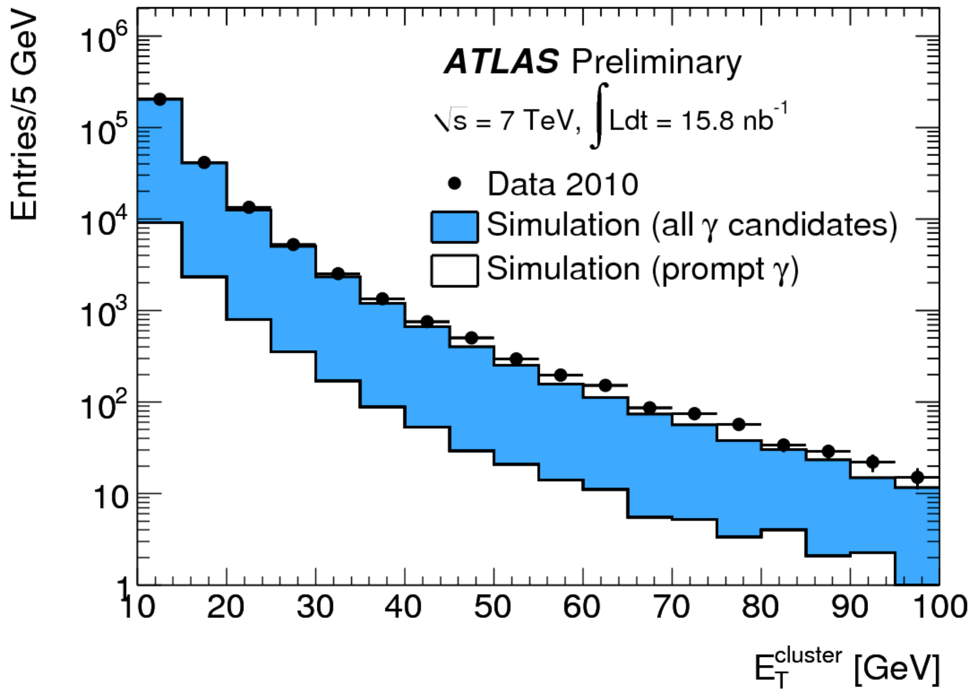
Cluster isolation E_T<5GeV in a cone

$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.4$$

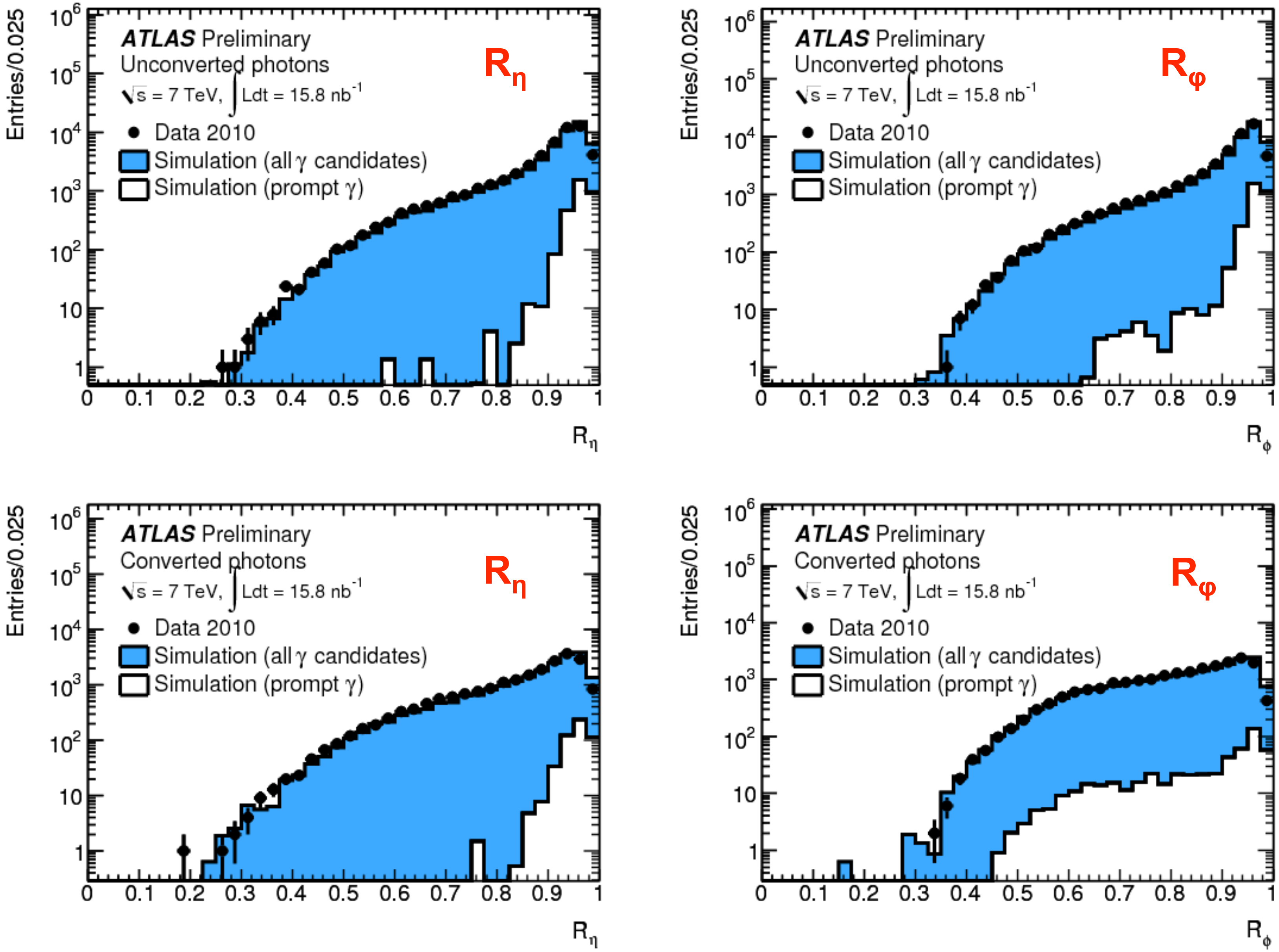
Initial selection:

- Photon cluster E_T>10GeV
- Cluster barycenter within $|\eta|<1.37$ or $1.52<|\eta|<2.37$
- Full cluster not overlapping with non-working readout optical links
- Hadronic leakage
- Cluster width in layer 2
- $R_\eta = E(3\times7)/E(7\times7)$

268992 candidates in 15.8 nb^{-1}



Signal/Background Discrimination



Unconverted photons

Converted photons

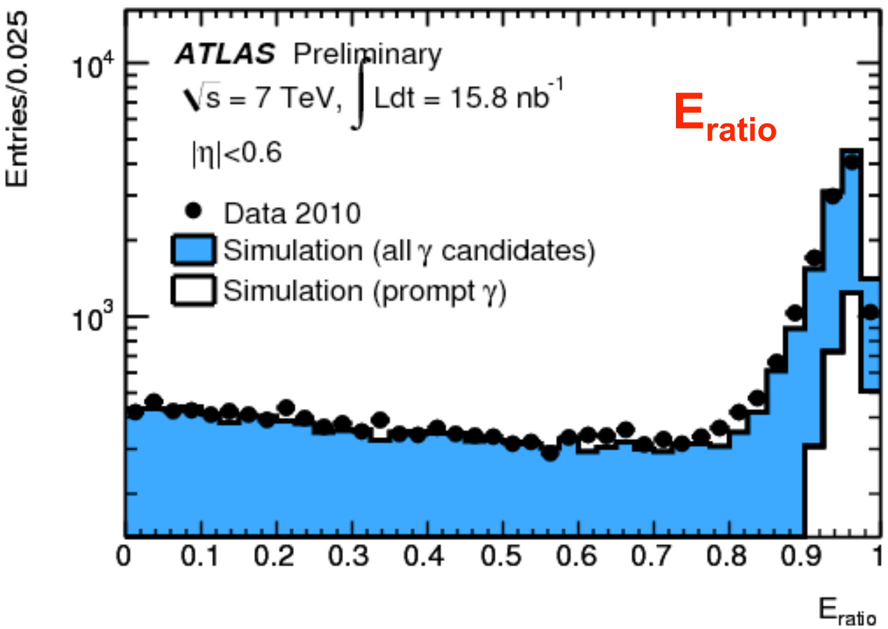
$R_\eta = E(3\times7)/E(7\times7)$ in $\eta\times\varphi$

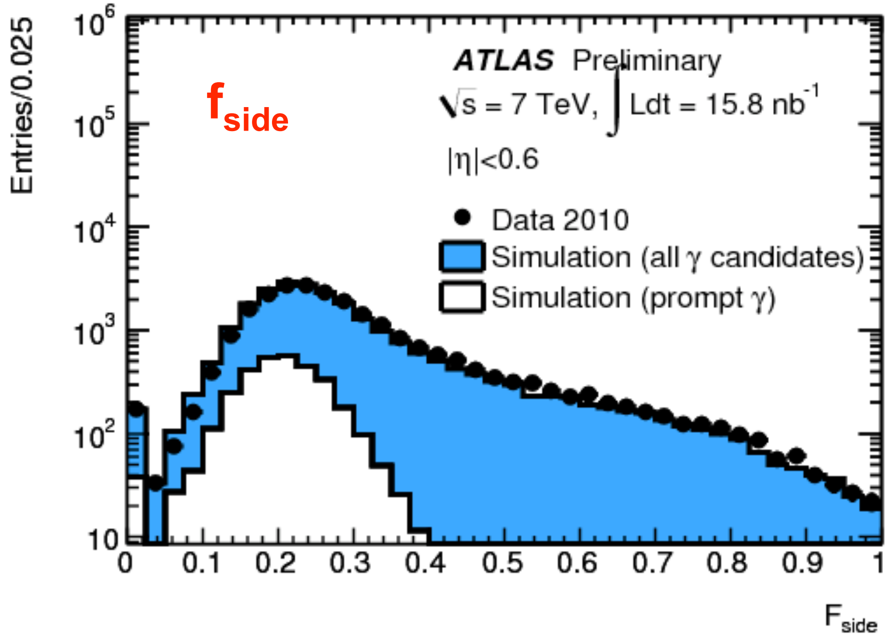
$R_\varphi = E(3\times3)/E(3\times7)$ in $\eta\times\varphi$

Signal/Background Discrimination

Tight selection:

- Apply additional selection using shower shapes in layer 1 of EM calorimeter
  - E_{ratio} = Asymmetry between first two maxima in layer 1
  - f_{side} = Amount of cluster energy outside the core 3 cells
- Results in improved π^0 rejection





- Tight selection criteria different for converted/unconverted photons
- Independent of photon E_T, depend only on photon η
- Layer 1 shower shapes not as well described by simulation at high η
  - Calorimeter detector description
  - Cross-talk between cells

11890 candidates after tight selection in 15.8 nb^{-1}

Calorimeter Cluster Isolation

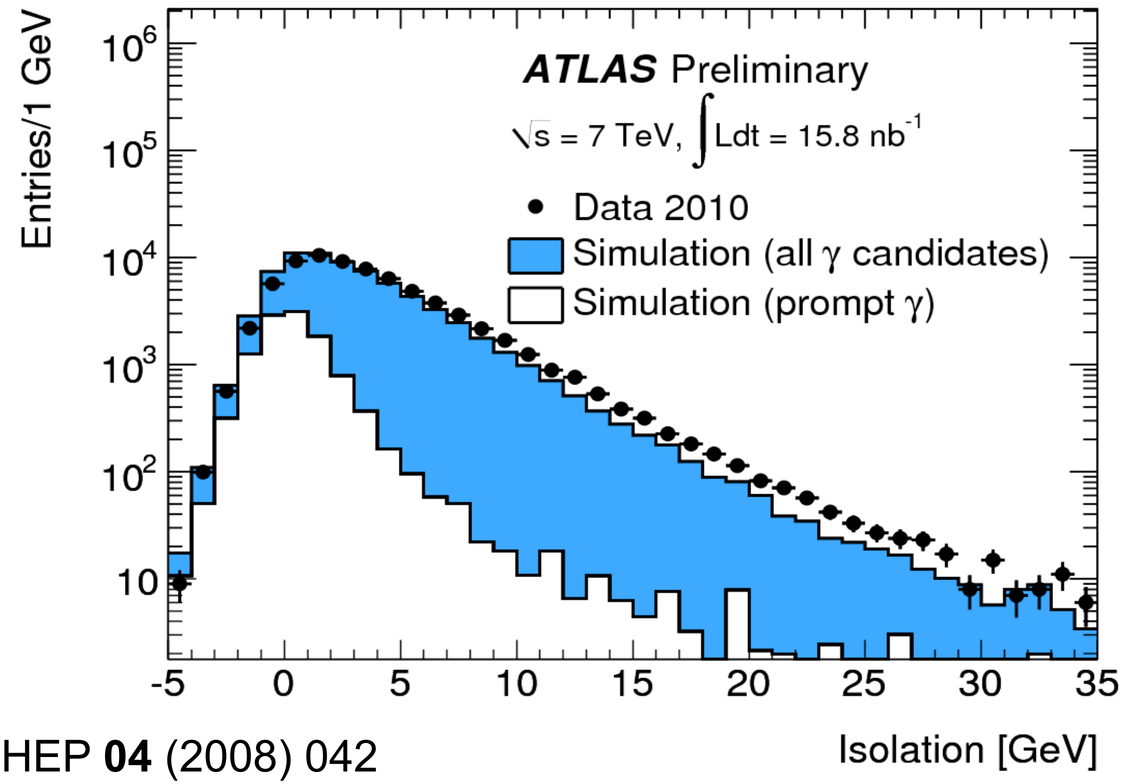
- Direct photon signal more isolated from hadronic activity than background from π^0
- Cluster isolation defined as energy deposited in a cone ΔR defined as:

$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.4$$

where the photon candidate energy itself is not included in the computation

- To better model it corrections are applied:
  - Photon E_T corrections to account for energy leakage outside the cone of interest
  - Corrections to remove residual activity from underlying events, pileup etc.[1]
- Signal region: < 3GeV

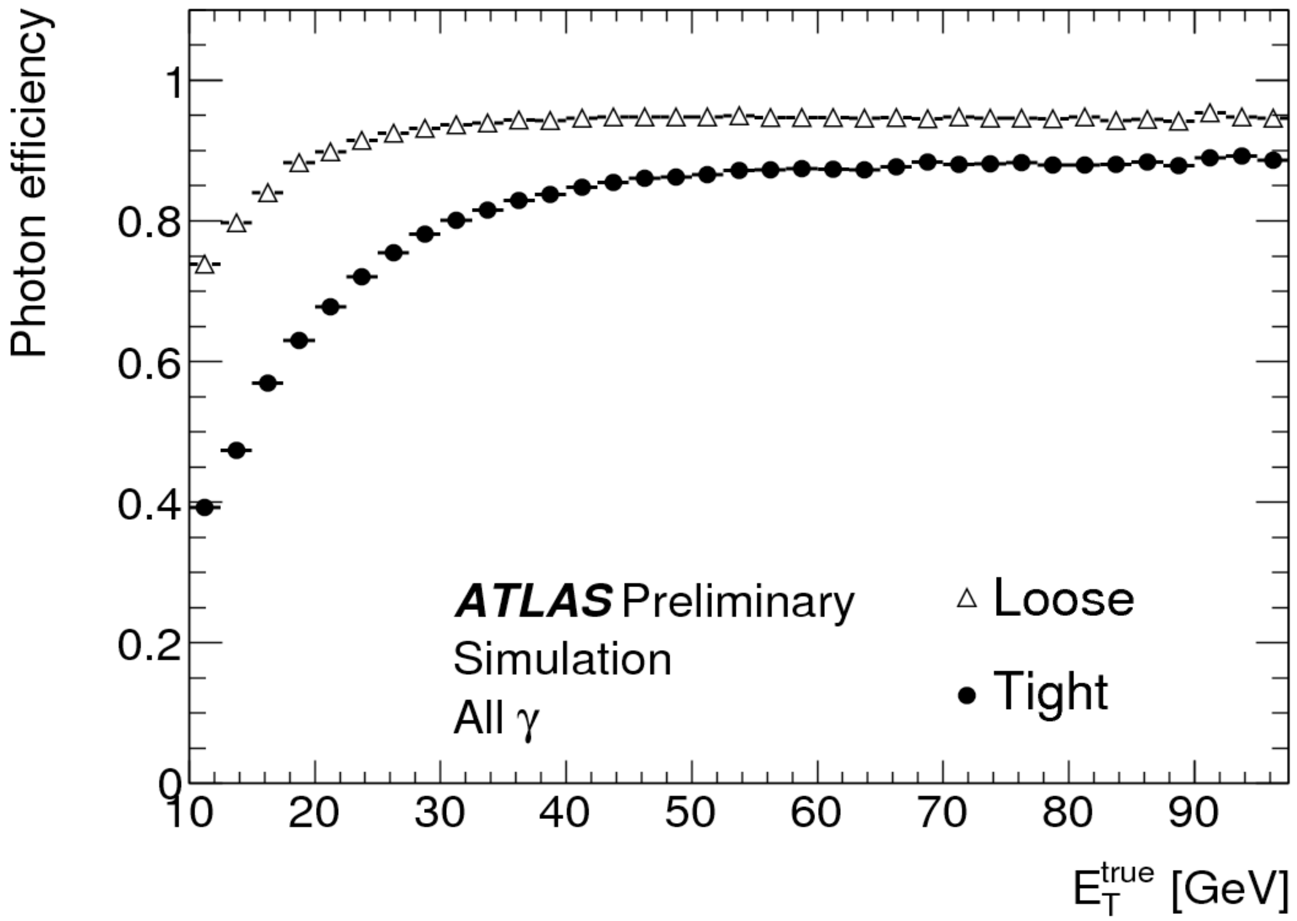
Direct photon isolation for both converted/unconverted photons after the tight selection applied



[1] M. Cacciari, G.P.Salam, G.Soyez, JHEP **04** (2008) 042

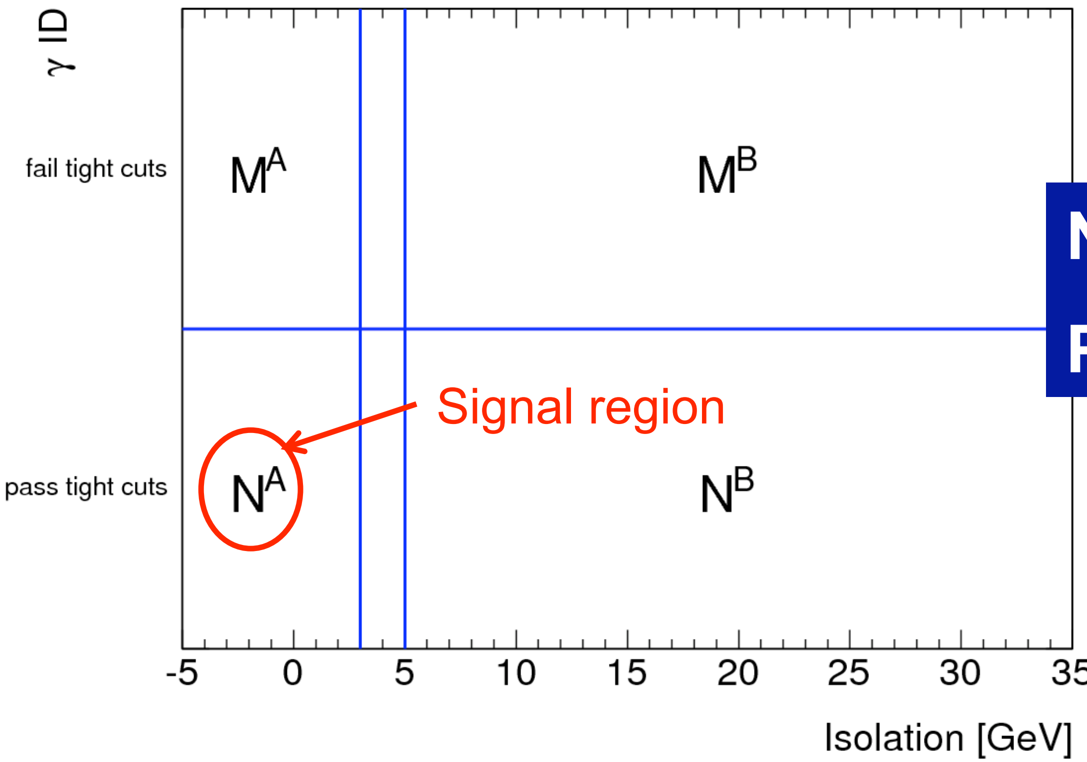
Direct Photon Identification Efficiency

- Photon identification efficiency is determined from the simulation after tight selection
- Systematic uncertainties include:
  - Material in front of the EM calorimeter: 0.3% decrease in efficiency per 1% material increase
  - Cross talk between calorimeter cells: 2% at E_T~10GeV for 50% increase in cross-talk
  - Background composition modeling (derived from shower shapes): 5-10%
    - In future use clean electron sample for more realistic estimations
  - Converted/Unconverted photon classification: 1% for 10% error in classification



Purity Estimation

- Simulation cannot be trusted to accurately predict the fake rate
- Use the cluster isolation and shower shapes on 1st layer for a data driven method
- Define as signal photons that pass the 1st layer shower shape and isolation criteria
- Define as background photons that fail any of the two
- Assumptions:
  - Signal contribution to background regions negligible
  - For background isolation independent of shower shapes in first calorimeter layer



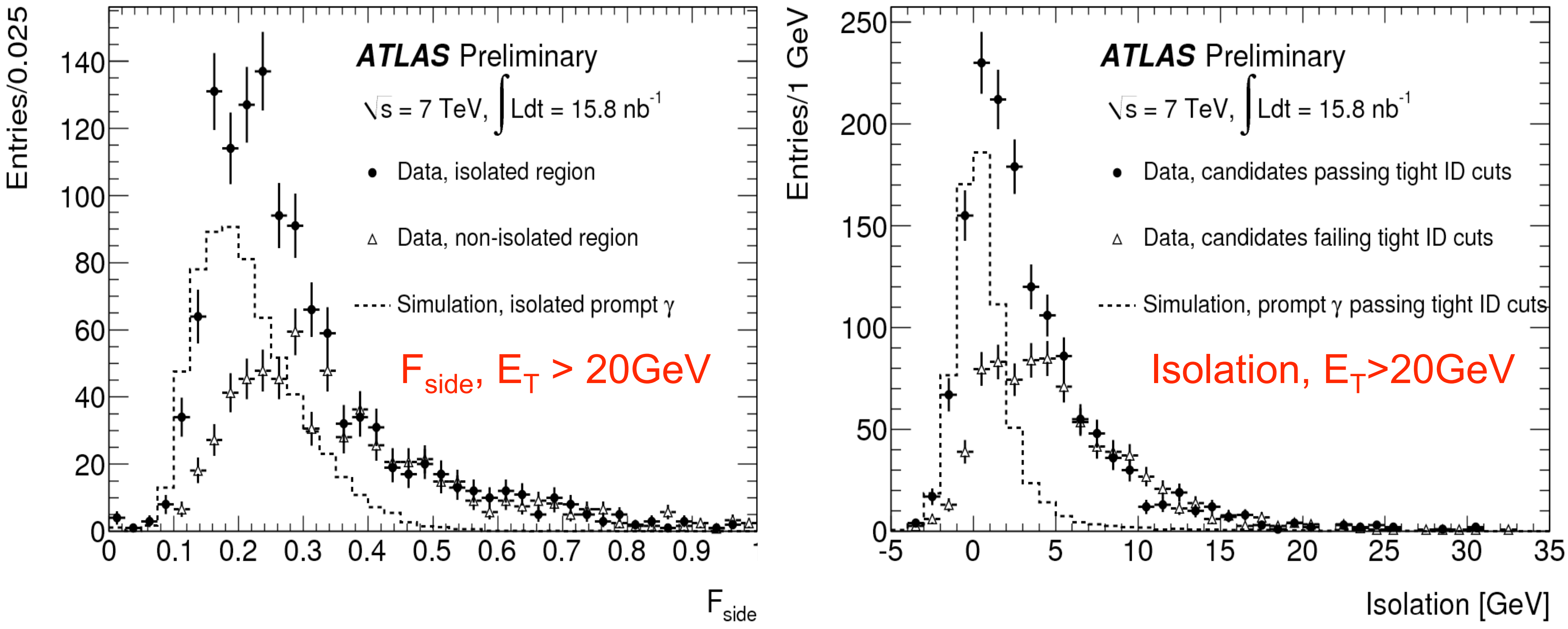
$$N^A_{Sig} = N^A - N^B\, M^A/M^B$$

$$P = 1 - (N^B/N^A_{Sig})\,(M^A/M^B)$$

Assumptions above don't hold exactly; corrections are applied, uncertainties included in systematics

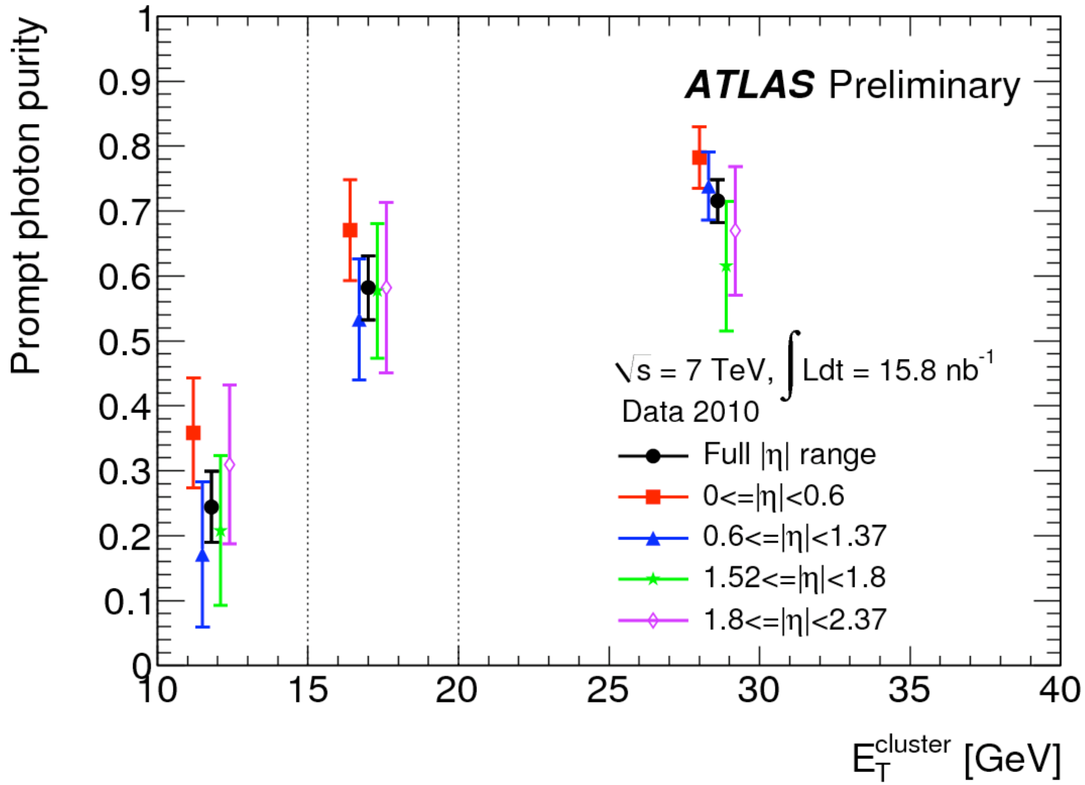
Purity Estimation

- Make distributions of 1st layer shower shape variables and isolation
- Split into two regions of interest:
    - Regions "A", isolated background region and signal region
    - Regions "B", non-isolated background control regions
- Take background shape from regions "B", normalize to isolation rejection M^A/M^B
- Look at excess of signal over background in region of interest



Excess is seen for signal over the background at small values of f_{side} and isolation (signal region) compatible with expectations from the simulation

Direct Photon Results



Photon candidate sample purity as a function of photon E_T,η

	N_{Cand}	Purity [%]	N^A_{Sig}
$10 \leq E_T < 15$	5271	24±5±24	1289±297±1362
$15 \leq E_T < 20$	1213	58±5±8	706±69±86
$E_T \geq 20$	864	72±5±6	618±42±59
(Uncertainties are ±stat. ±syst.)			

Systematic Uncertainties

	$10 \leq E_T < 15$	$15 \leq E_T < 20$	$E_T \geq 20$
Alternative non-isolated control region	496	19	11
Alternative identification region	1100	25	25
Signal inefficiency	176	39	31
Signal composition	35	18	21
Isolation-identification correlation	496	56	16
Energy scale	348	38	33
Total	**1362**	**86**	**59**

Systematic uncertainties on signal

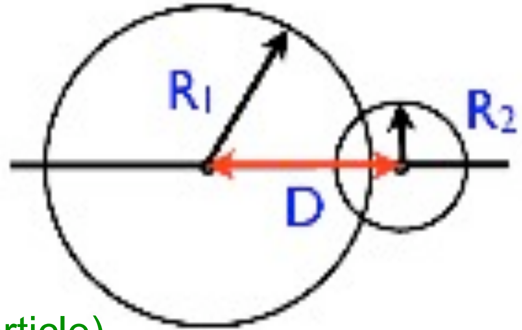
	$10 \leq E_T < 15$	$15 \leq E_T < 20$	$E_T \geq 20$
Alternative non-isolated control region	0.03	0.02	0.01
Alternative identification region	0.21	0.02	0.03
Signal inefficiency	0.03	0.03	0.04
Signal composition	0.01	0.02	0.02
Isolation-identification correlation	0.10	0.05	0.02
Energy scale	0.05	0.05	0.01
Total	**0.24**	**0.08**	**0.06**

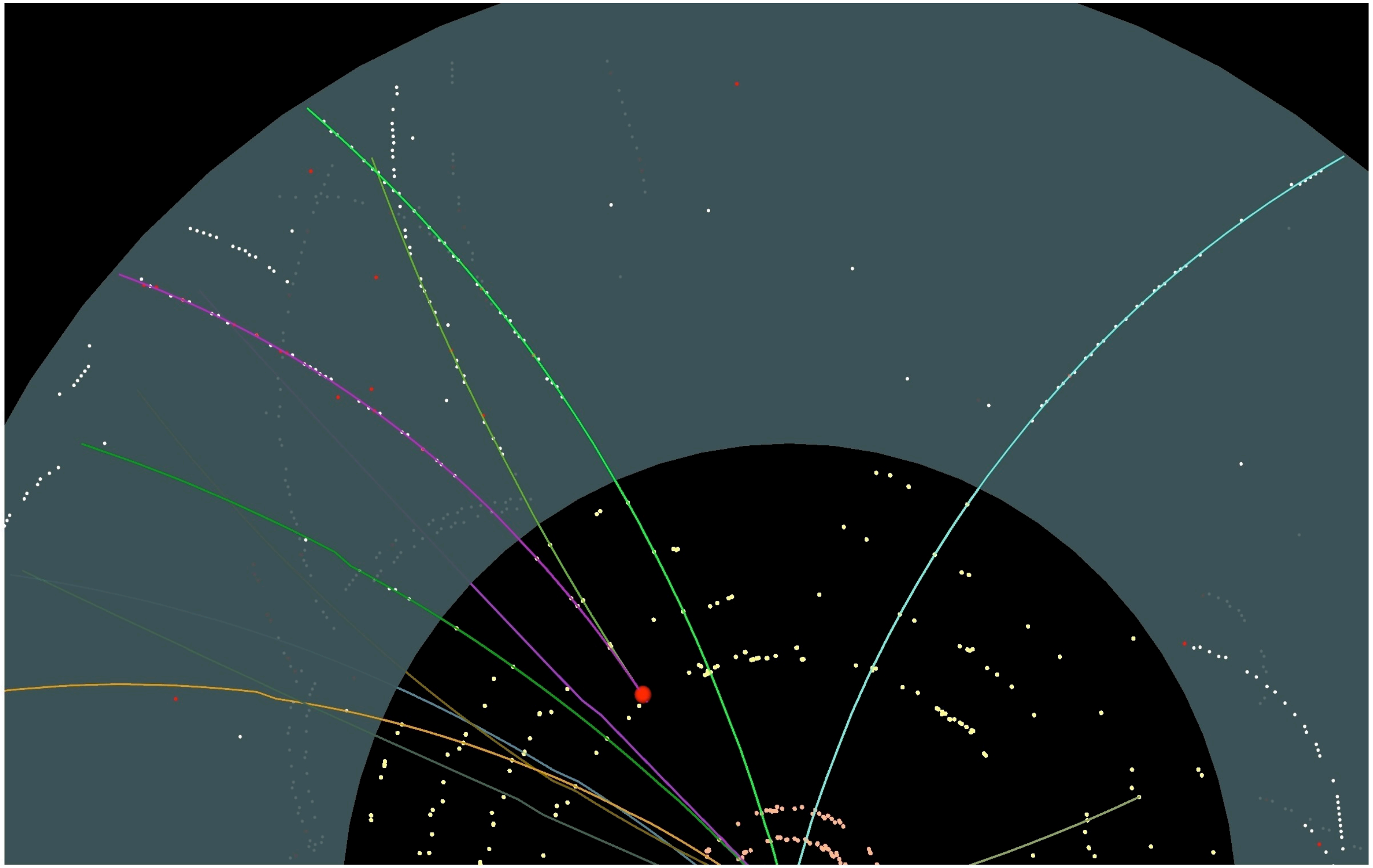
Systematic uncertainties on purity

- Converted/Unconverted photons: 0.49±0.07 converted, E_T>15GeV (expect 0.45±0.01)
- Signal yield varies by <2% in different pseudorapidity regions

Converted Photon Reconstruction

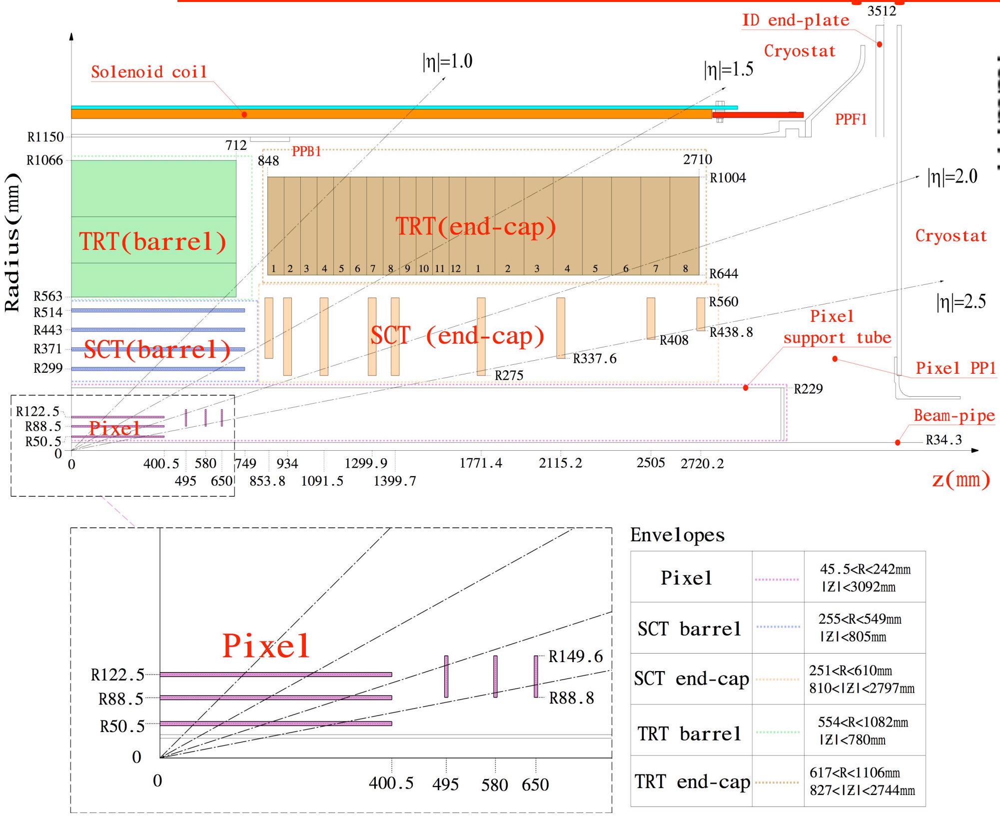
- Tracks are selected based on their particle identification probability for being electrons
- Pairs are formed using opposite charge tracks
- Track pairs are selected according to the following criteria:
  - Distance of minimum approach between the two tracks in the pair
  - Opening angles in θ and ϕ
  - D-R1-R2 as shown in the figure
- Selected pairs are passed to the vertex fitter:
  - Constrained fit where $\Delta\theta=\Delta\phi=0$ is required (equivalent to massless particle)
  - Additional selection using the fit χ^2

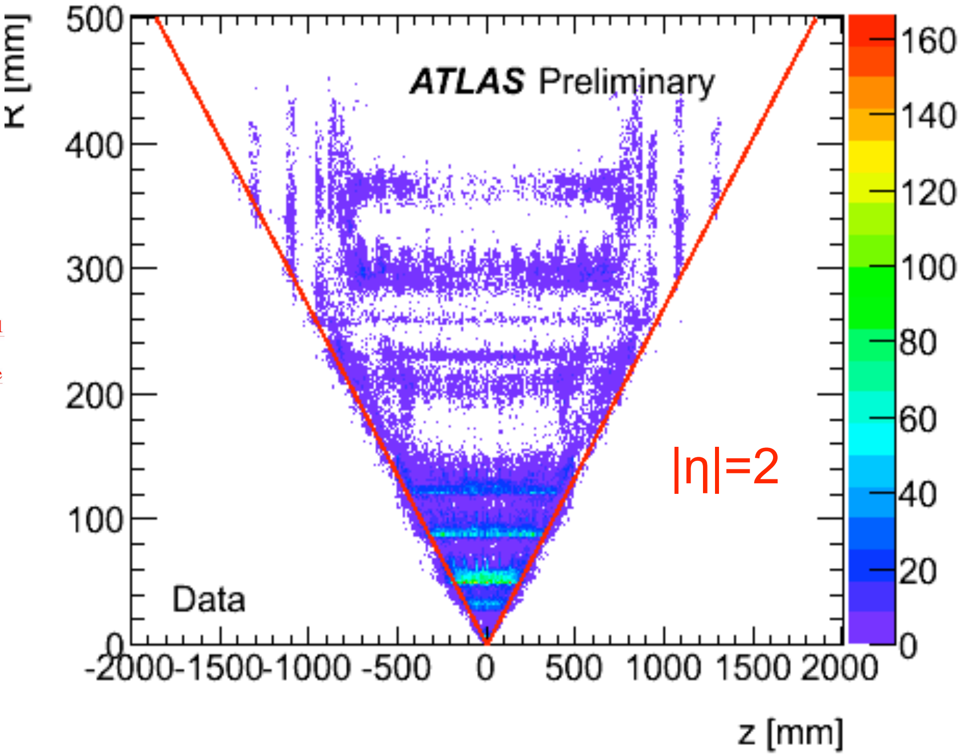




Converted photon event display from a 900 GeV data run

Tracker Material Mapping: (R,z) Distributions





Can use the reconstructed conversion vertex radial position to map the material in the ATLAS tracker

- Data-driven procedure for comparing to and correcting the tracker description in MC

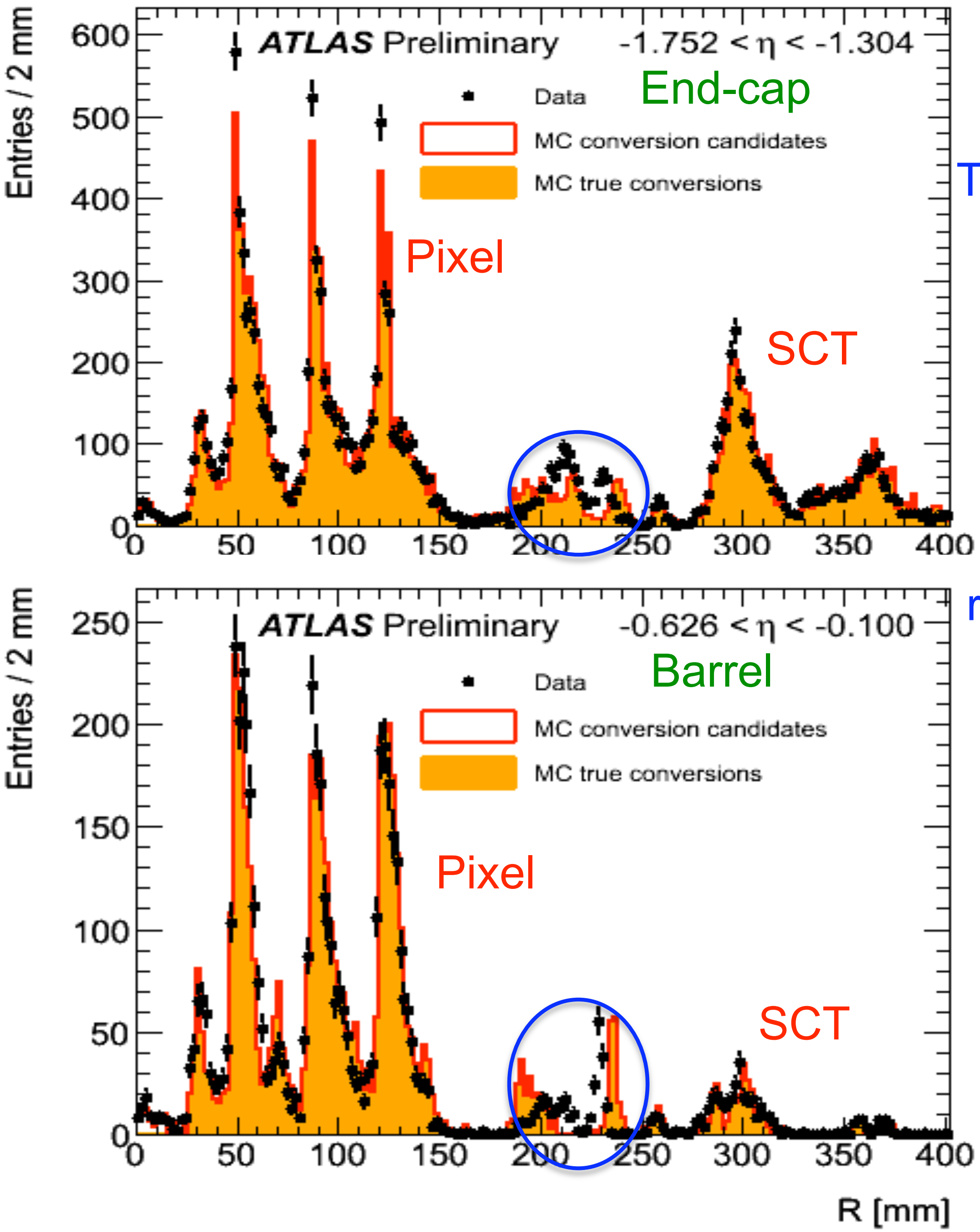
ATLAS tracker radiogram using converted photons:

- Three barrel (|η|<1) pixel layers are visible
- The first two barrel SCT layers and the first end-cap disks are also visible
- Red line corresponds to |η|=2 above which conversion reconstruction is inefficient

Conversion reconstructed radial position resolution of ~3mm in pixel tracker

Statistical precision already at <5% level with ~14 nb^{-1} integrated luminosity

Tracker Material Mapping: Radial Distributions



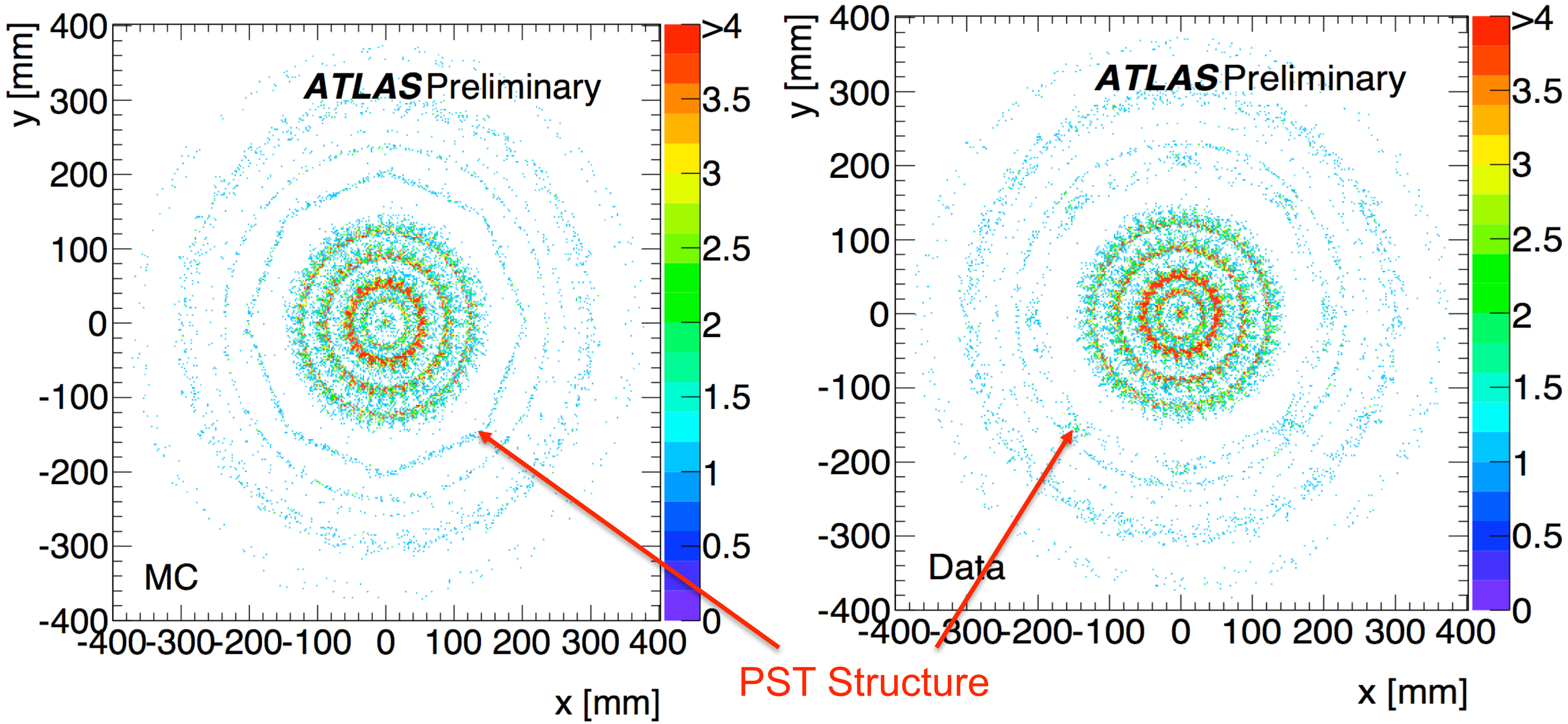
The beam pipe, pixel and SCT structures are clearly visible

Overall good agreement between data and simulation

Discrepancies between data and the simulation, e.g. in the pixel support region, can be identified and eventually corrected

Purity of reconstructed conversions very high (>90%)

Tracker Material Mapping: (x,y) Distributions

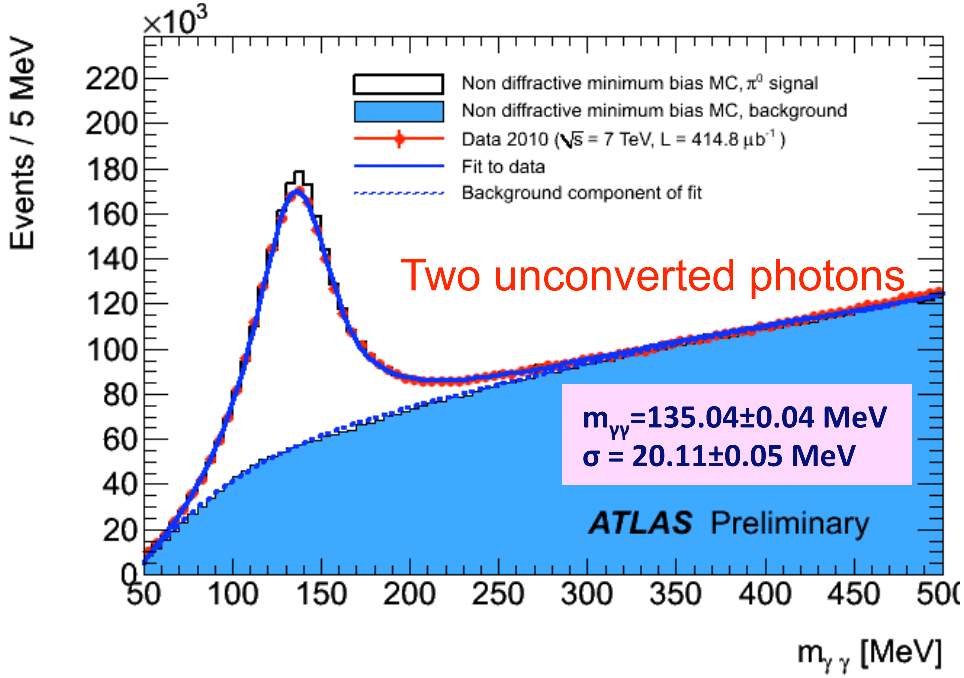


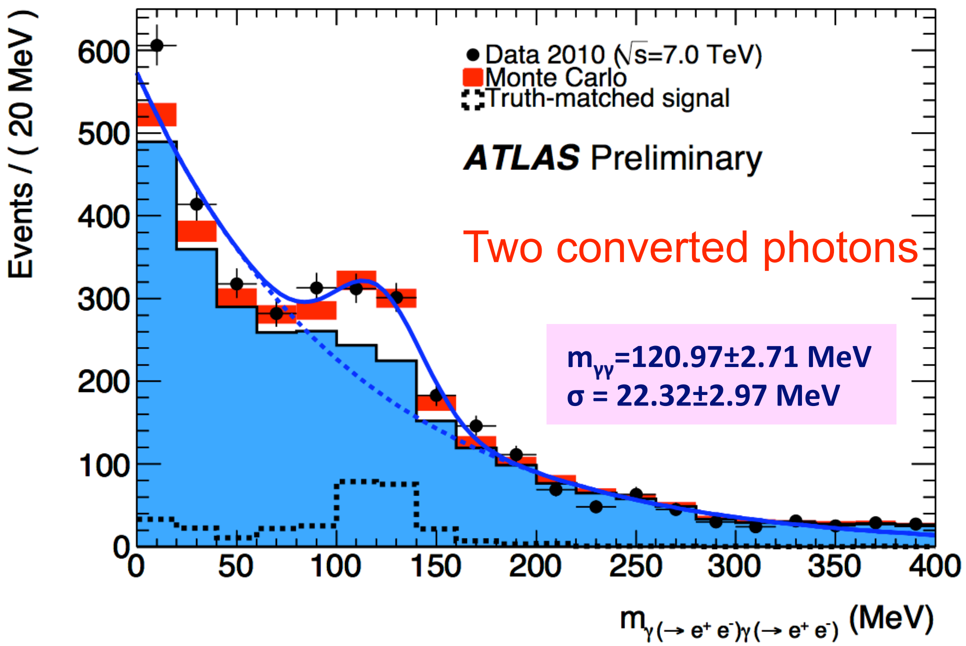
Reconstructed conversion vertices locations on the bending plane (x,y):

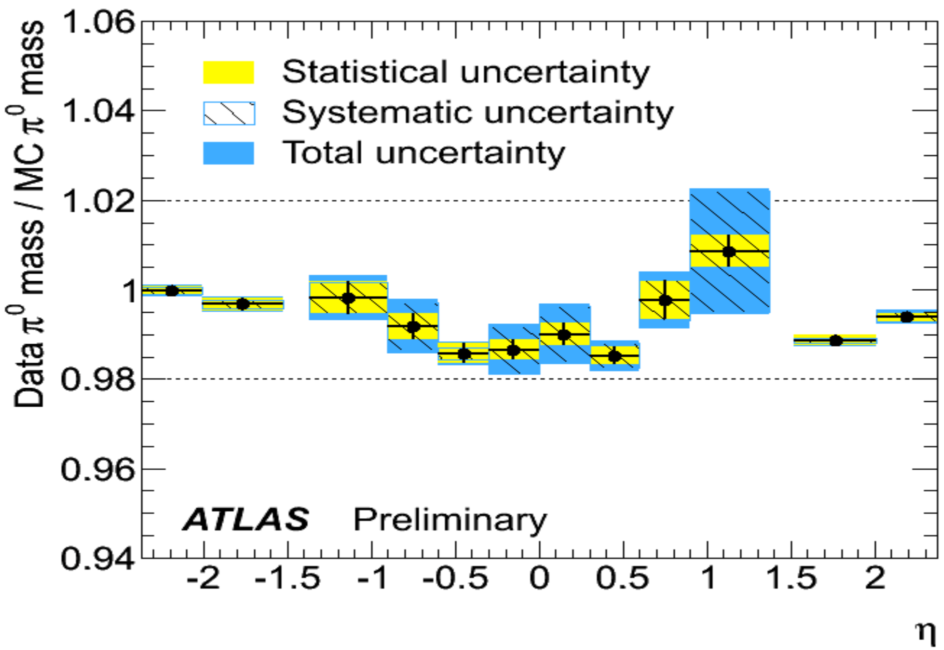
- Projection over Si-tracker barrel pseudorapidity range (|η|<1.0)

Results have already been used in improving the ATLAS tracker description in the simulation

Reconstruction of π^0(di-photon) signal







Can be used for establishing uniformity of the EM calorimeter response:

- EM energy scale known to better than 2%
- Uniformity in φ within 0.7%

Summary

- ATLAS and the LHC are performing well:
  - Luminosity is increasing rapidly
  - Sub-systems operational ~100% of the time
- First analyses of 7 TeV data are very encouraging:
  - Observation of prompt electrons
  - Observation of prompt photons
  - Observation of W/Z decays in the electron channel
  - Detailed mapping of the tracker material with converted photons
- Larger samples of electrons from J/ψ and Z decays are becoming available
  - Work on the electromagnetic energy scale has commenced
- Quite some work in progress:
  - Detailed understanding of variables used in e/γ identification
  - Measurement of identification efficiency
  - Precise calibration of the energy scale
  - Calorimeter uniformity measurements
  - Material effects inside the tracker

Leading towards physics measurements and new discoveries in the e/γ channels!

Backup Slides

$W \longrightarrow e\nu$ Reconstruction

Electron selection:

- E_T > 20GeV, $|\eta|$ < 2.47, exclude barrel/endcap gap in 1.37 < $|\eta|$ < 1.52
- Reject electron clusters in problematic regions of the EM calorimeter
- Shower shapes in 2nd EM calorimeter layer
- Shower shapes in 1st EM calorimeter layer

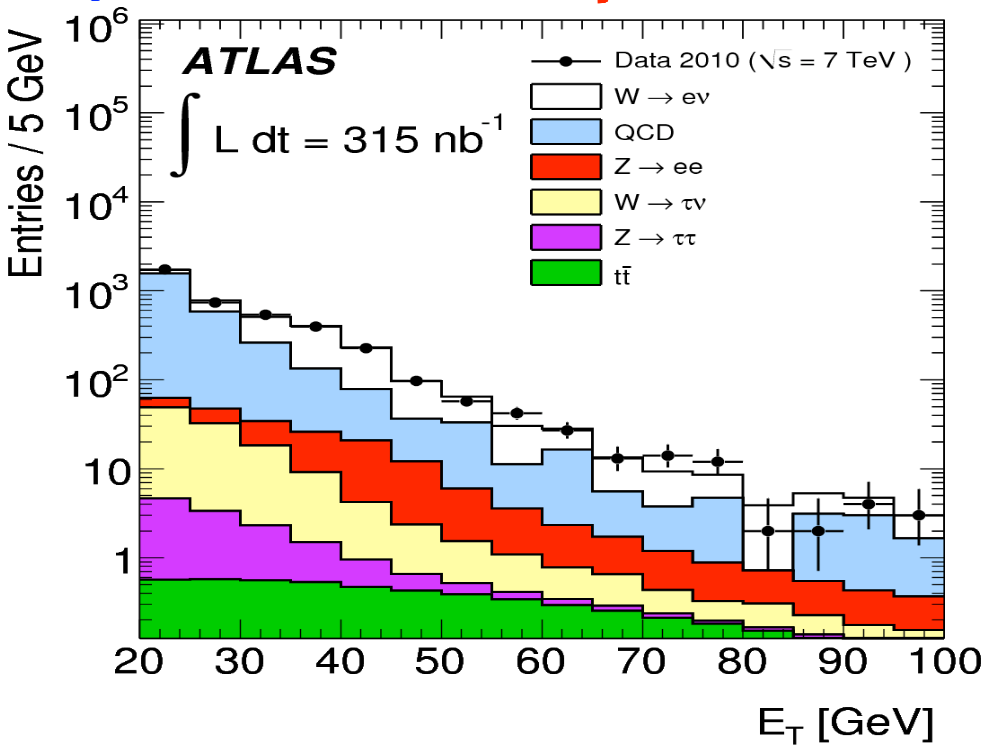
Main hadronic background rejection

- Track-to-cluster match quality
- Track quality (impact parameter, b-layer hits)

Conversion rejection, PV tracks

- E/p ratio
- High Threshold TRT hits

"Tight" electron selection

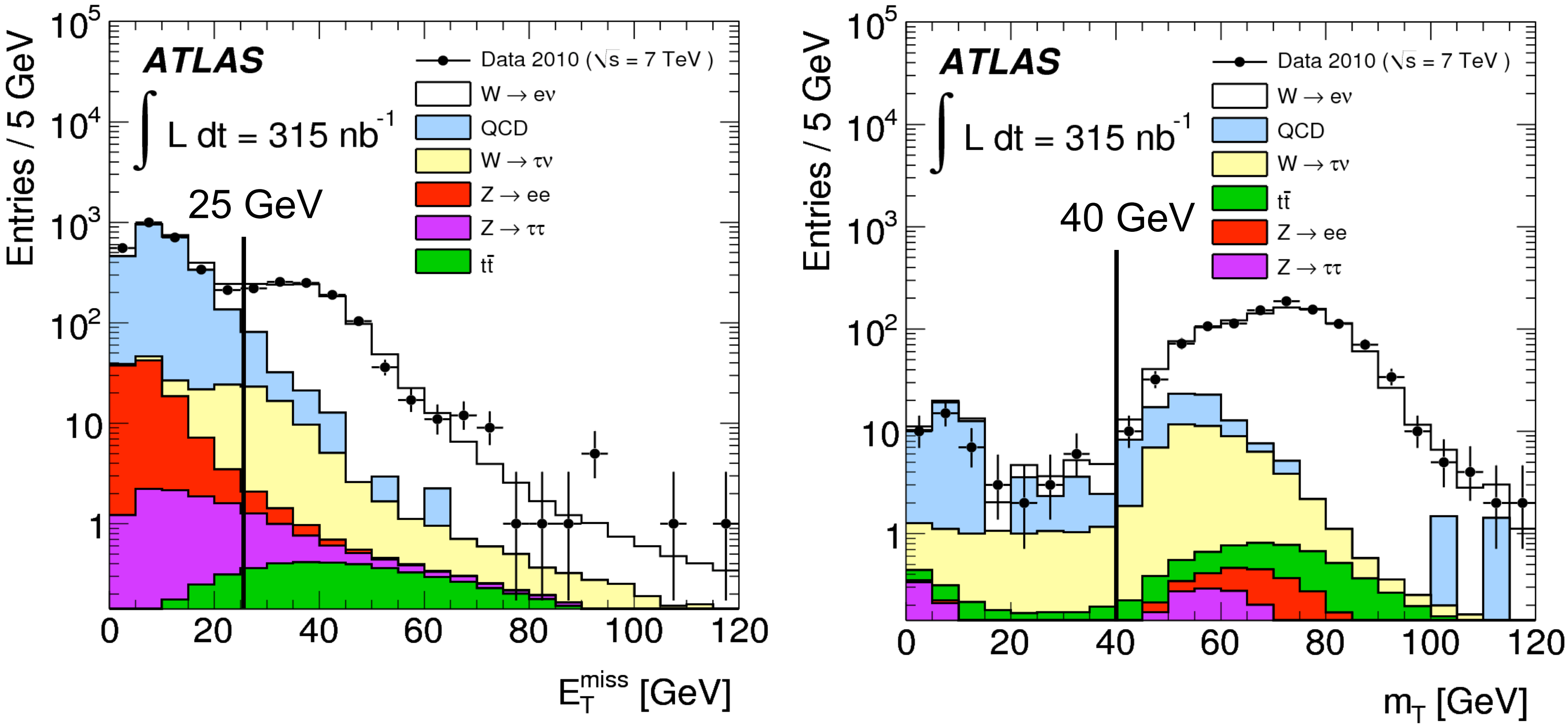


MC normalized to integrated luminosity of the data using a PYTHIA estimated cross-section and scaling the QCD background prediction by a factor of 2.4

W⟶eν Reconstruction

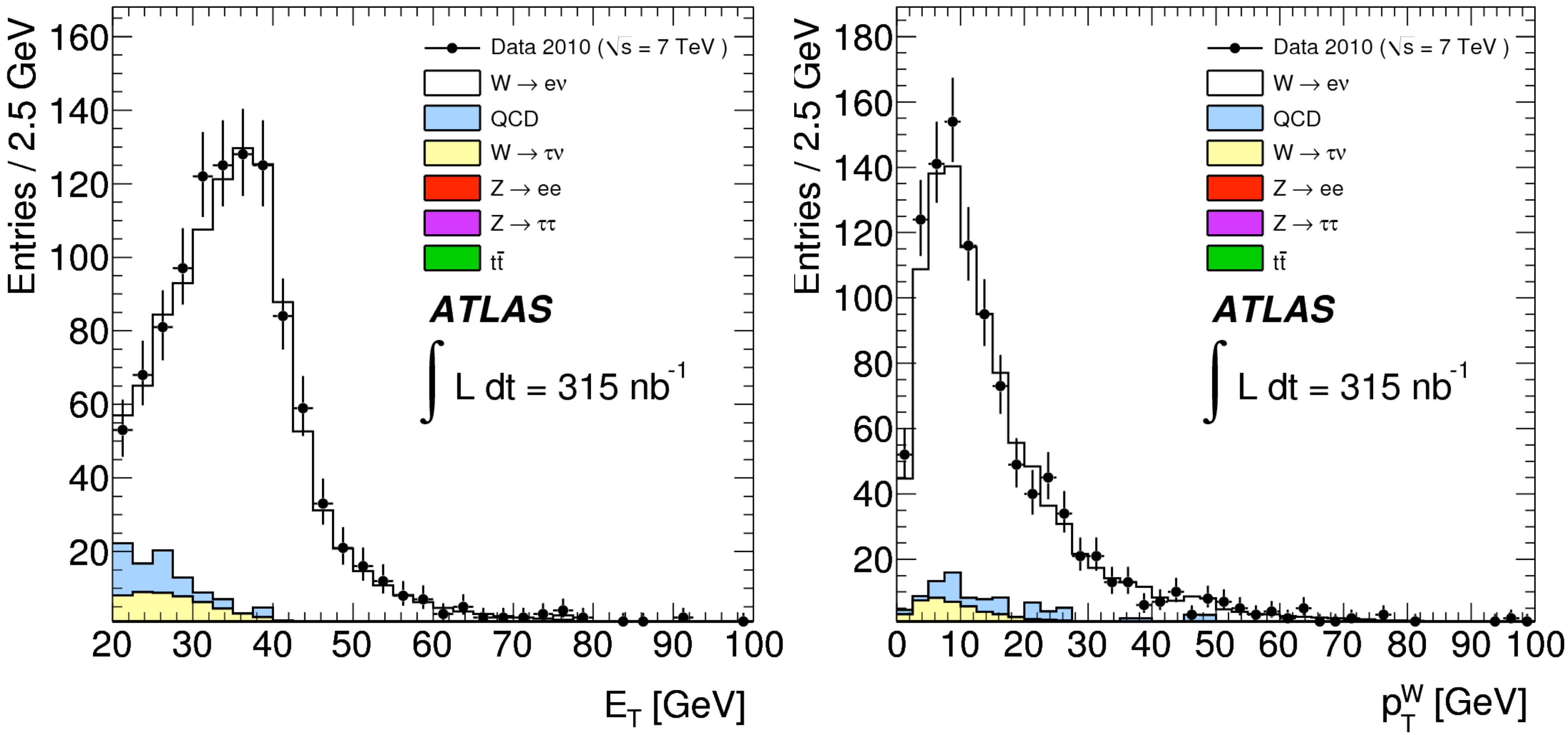
Kinematic selection:

- Electron with E_T > 20GeV
- Missing transverse energy E_T^{miss} > 25GeV
    - Baseline estimation from calorimeter clusters corrected to hadron energy scale
- Transverse mass of the lepton-E_T^{miss} system m_T > 40GeV
    - Defined as: $m_{\mathrm{T}} = \sqrt{2\, p_{\mathrm{T}}^{\ell} p_{\mathrm{T}}^{\nu}(1 - \cos(\phi^{\ell} - \phi^{\nu}))}$



W⟶eν Reconstruction

1069 W⟶eν candidates (637 e^+, 432 e^-)



Backgrounds in the W sample:

- Z(ee), Z(ττ), W(τν): ~30 events estimated from simulation
- Data-driven estimation of QCD background (use E_t^{miss} as discriminating variable): 28±3(stat.)±10(syst.) events

$Z \longrightarrow ee$ Reconstruction

"Medium" electron selection:

- E_T > 20GeV, |η| < 2.47, exclude barrel/endcap gap in 1.37 < |η| < 1.52
- Reject electron clusters in problematic regions of the EM calorimeter
- Shower shapes in 2nd EM calorimeter layer
- Shower shapes in 1st EM calorimeter layer

Main hadronic background rejection

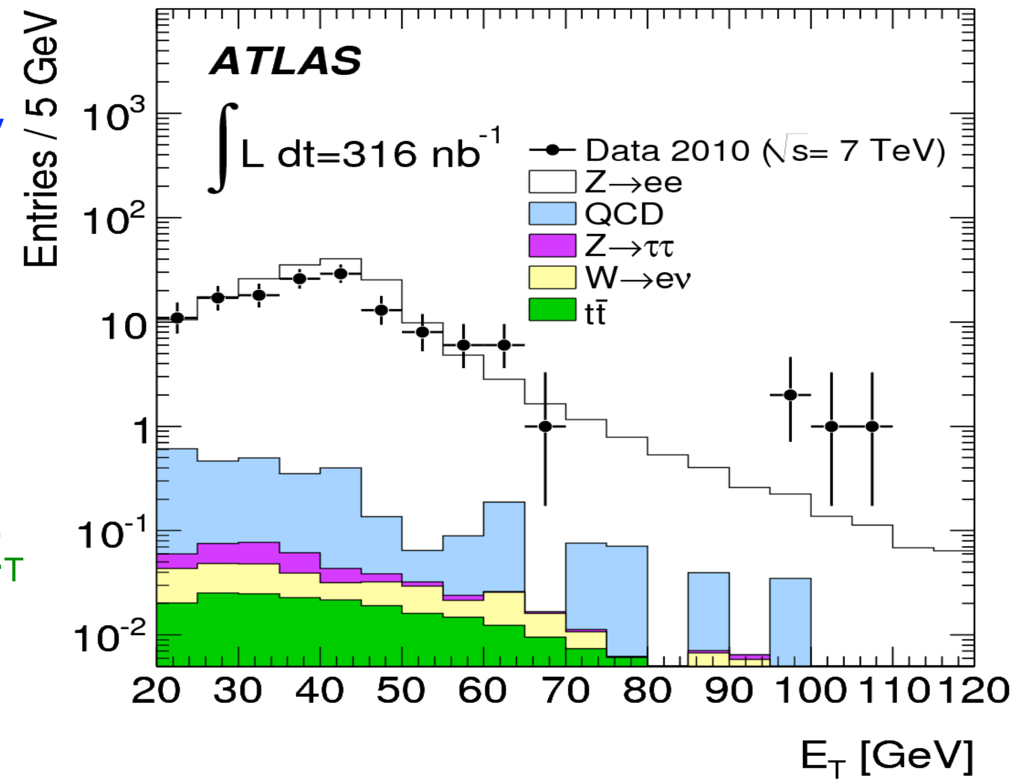
- Track-to-cluster match quality
- Track quality (impact parameter, b-layer hits)

Conversion rejection, PV tracks

Kinematic selection:

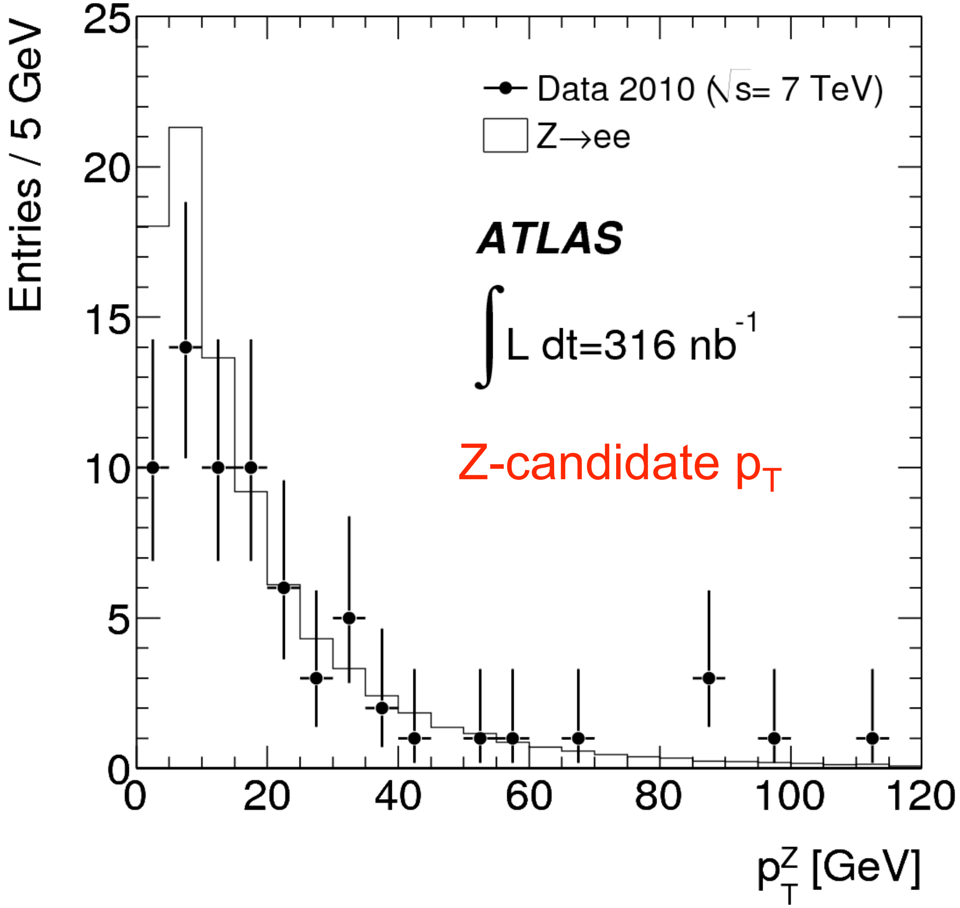
- Pair of oppositely charged electrons
- Invariant mass window: $66<m_{ee}<116$ GeV
- Veto events with ≥3 "medium" electrons

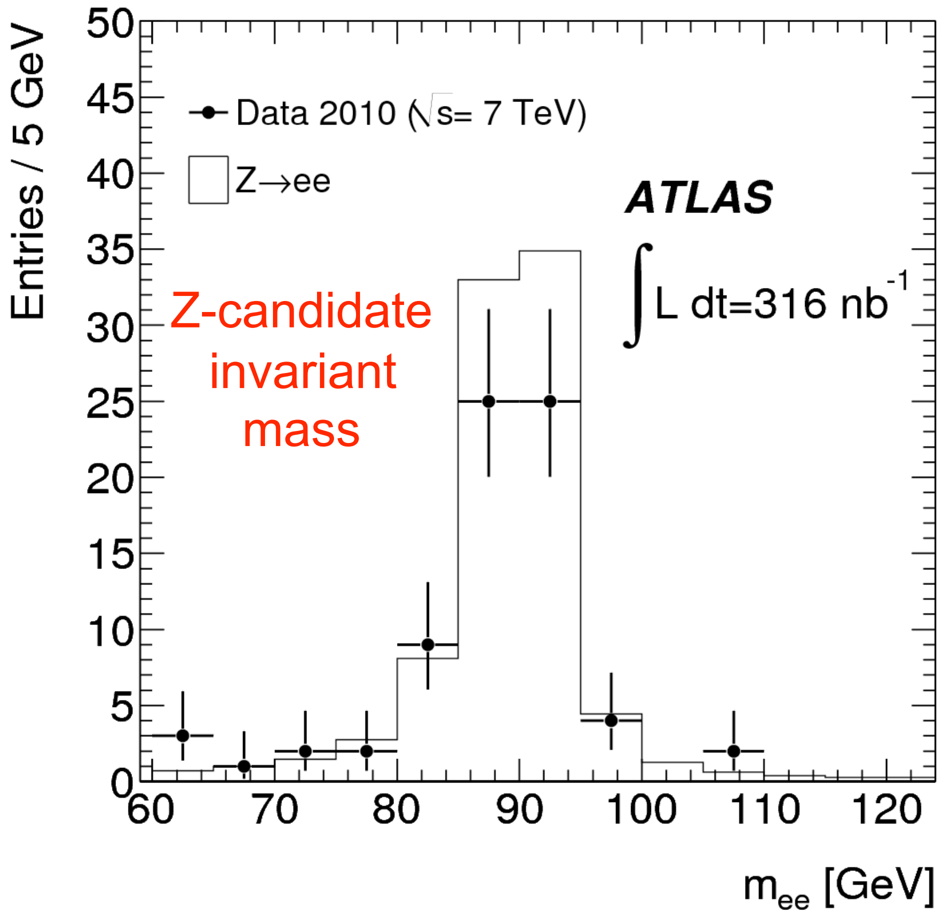
70 $Z \longrightarrow ee$ candidates



Distribution of the electron cluster E_T from the selected Z candidates

Z⟶ ee Reconstruction



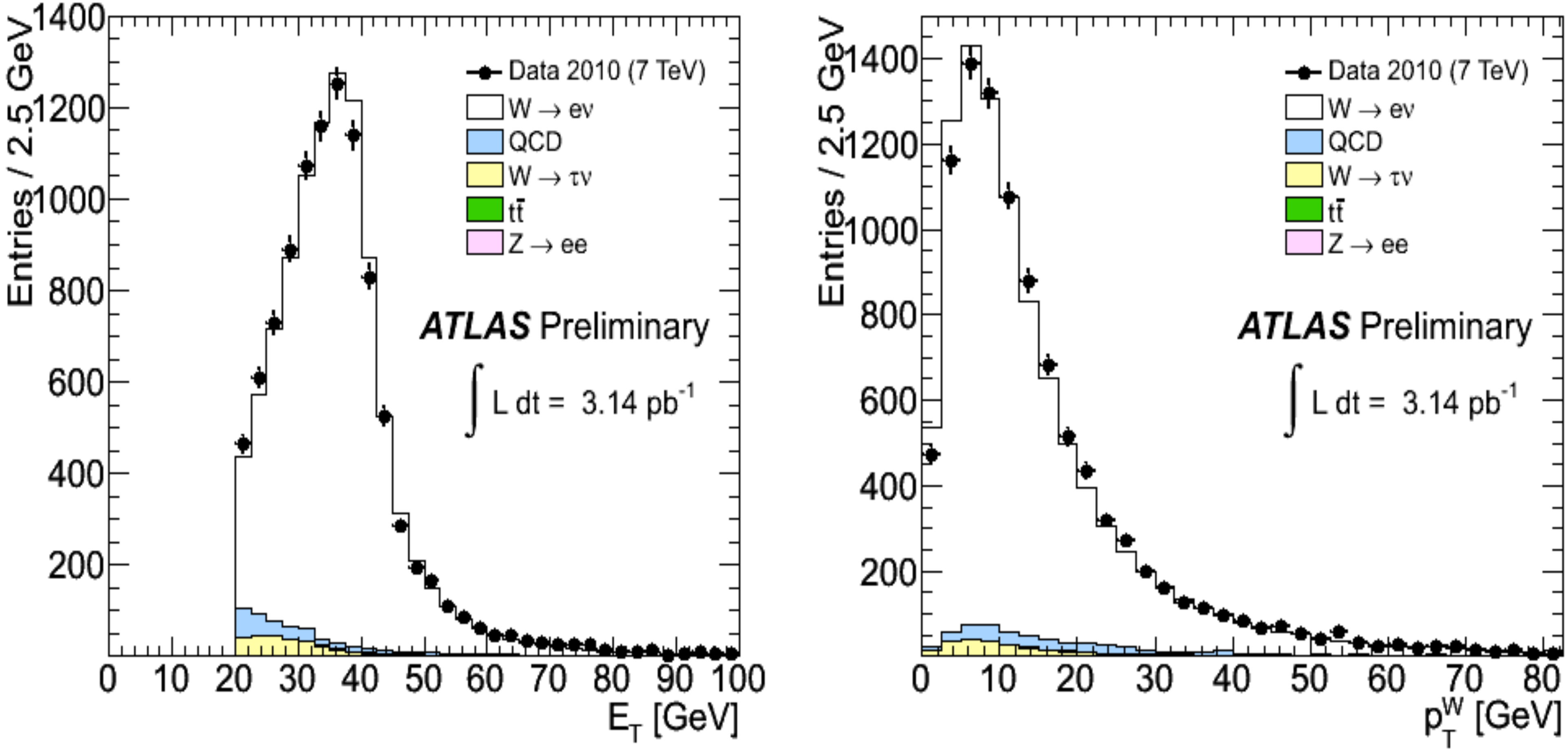


Backgrounds in the Z sample:

- W(eν), Z(ττ), tt-bar: ~0.3 events estimated from simulation
- Data-driven estimation of QCD background (relax electron selection, reconstruct invariant mass distribution): 0.91±0.11(stat.)±0.41(syst.) events
- Same charge pairs after Z selection: 3 plus additional 0.9 from QCD background

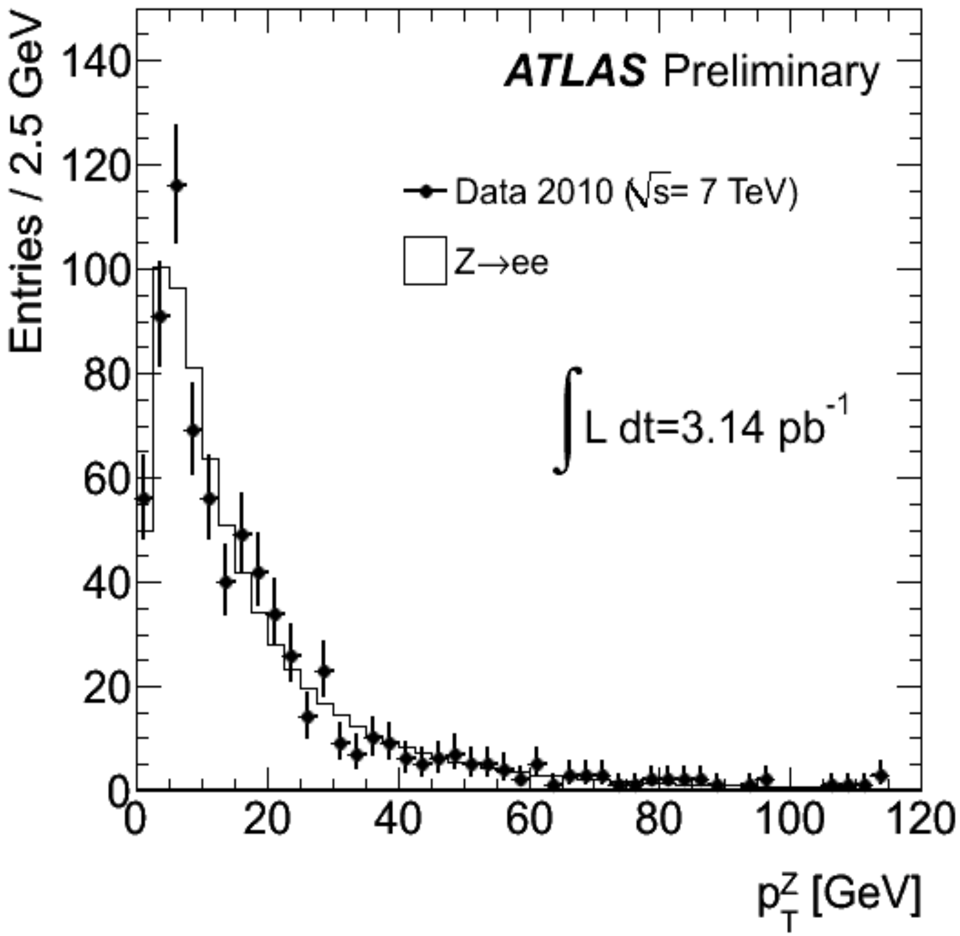
Updated $W \longrightarrow e\nu$ kinematic properties

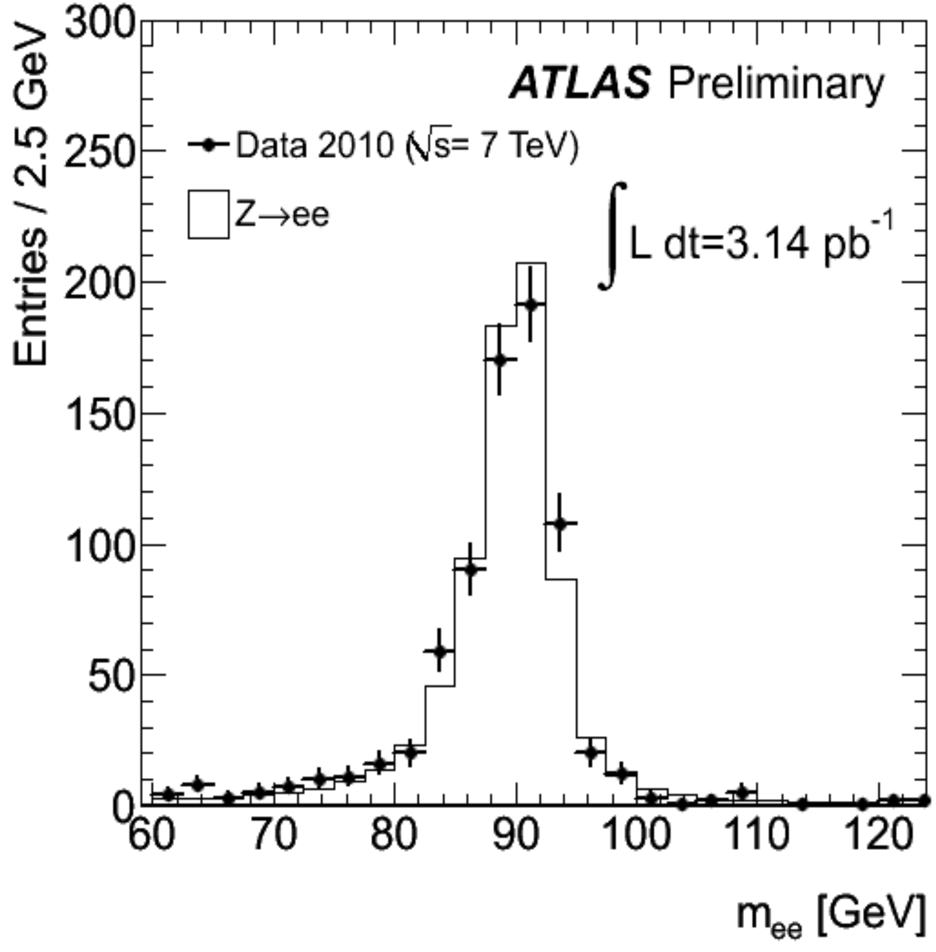
Integrated luminosity $\int\mathcal{L}$=3.14 pb^{-1}



Updated Z ⟶ ee Kinematic Properties

Integrated luminosity $\int\mathcal{L}$=3.14 pb^{-1}





Tracker Material Estimation using Converted Photons

Number of converted photons related to the amount of material in radiation lengths X_0 traversed:

$$\frac{X}{X_0} = -\frac{9}{7}\ln(1 - F_{\mathrm{conv}})$$

where

$$F_{\mathrm{conv}} = \frac{N_{\mathrm{reco}}}{N_{\mathrm{tot}}}\frac{F_{\mathrm{comb}}F_{\mathrm{mis}}}{\epsilon}\frac{1}{\exp(-7/9M_{\mathrm{up}})}$$

F_{conv}	fraction of converted photons
N_{reco}	number of reconstructed conversions
N_{tot}	initial number of photons
M_{up}	material upstream of given layer
F_{comb}	correction for combinatorial background
F_{mis}	correction for resolution effects
ϵ	efficiency

$F_{\mathrm{comb}}, F_{\mathrm{mis}}, \epsilon$ are currently evaluated from the simulation

Can use the reconstructed conversion vertex radial position to map the material in the ATLAS tracker

- Data-driven procedure for comparing to and correcting the tracker description in MC